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Regulation of Use and Application of Herbal Natural Products and Supplements in Sports Performance Enhancement

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Abstract

The use of herbal natural products and food supplements by athletes has generated a global concern in the last decades. Studies have shown that some herbs are used to enhance muscle strength and body mass and that the health benefits from plants are associated to their bioactive compounds such as polyphenols, terpenoids, and alkaloids which have varying physiological effects on the human body. More pharma companies are launching numerous products with prohibited active metabolites or fake supplement that can induce harmful side effect and potential drug-herbal interactions. So far, there is no assurance of confidence of safety (COS) for use in competitive sports. Although some food supplements herbal products are similar, clinical testing and understanding of most herbal natural remedies is lacking. Some herbal products have proven useful in an athletic setting; however, current United States Food and Drug Administration (FDA) regulations do not ensure safe and effective products. A descriptive review focusing on specific considerations for the athletic trainer is provided.

Conclusions/Recommendations: Despite their increasing tendency to seek natural therapies, athletes need to be aware that ''natural'' does not equal ''safe.'' Athletes are entitled to know that most herbs are not proven safe or effective under current FDA standards. The athletic trainer must be able to provide honest, unbiased information when educating athletes regarding herbal supplements.

We use a data mining approach to source information and data Sources through online search on MEDLINE/PUBMED, SPORT Discus, CINAHL, and Academic Search Elite databases 1990–2023 using the key words herbals, regulation, supplements, toxicity, and adulteration. The objective of this project review was to examine common herbal supplements, explore potential risks associated with herbal use, and provide recommendations to the athletes regarding health risk associated with herbal products and supplements. This paper also attempts to provide guidance on the efficacy and side effect of most used plants in sport.

Keywords: Herb-Drug Interactions; Herbal supplement; Toxicity; Regulations; Adulteration; Ergogenic Aid; Alkaloids; Polyphenol; Medicinal plant; Physical activity

Introduction

The use of herbal supplements in competitive sports has significantly gained popularity in the past two decades. Herbal products extracts derived from seeds, gums, roots, leaves, bark, berries, or flowers contain many phytochemicals of pharmaceutical importance grouped as polyphenols, including phenolic acids and flavonoids, alkaloids, glycosides, saponins, and lignans which are of potential health benefits [1]. The use of herbal products is regulated by the Food and Drug Administration (FDA) under a special category of foods; food supplement according to the Dietary Supplement Health and Education Act (DSHEA) of 1994 [1]. Studies have shown that 17% of female athletes have used herbal products in one form or the other [2]. In sport, most herbal supplements are used to enhance muscle growth and fat burning [3]. A different commercial product such as *SportPharm* which contains numerous phytochemicals, caffeine, Purple Willow Bark "Cayenne", "pepper" and "Ginger root", are reported to increase mental vigilance, stimulate fat-burning metabolism, and improves muscle performance [3]. Herbal supplements are currently used by athletes and non-athletes alike to improve endurance and strength performance [3]. However, many of these supplements have not been proven safe and effective under current FDA standards. Others herbal products and food supplements have been excluded from this requirement because they are potential sources of some regulatory approved drugs [4-6]. Those herbs need to be explored further in human consumption. Some common herbs indicated in Table 1, have been approved by FDA.

The use of herbal products and supplements by athletes have seen a steady increased despite the strict regulation and prohibition

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Table 1: Common herbal products and supplements with FDA Approval [1].

Herbs	Approved Use	Recommended Dosage	Adverse Effects/Warnings/Comments
Aloe barbadensis	Laxative	20-30 mg/d Anhydrous alone	Loss of electrolytes with chronic use; contraindicated if gastrointestinal obstruction is present; not for use for pregnant or lactating women.
Capsicum or *Cayenne pepper Capsicum spp* (fruits)	Topical analgesic/counter Irritant	50 mg capsaicin in 100 mg neutral base; use beyond 2 days is not recommended.	Avoid touching eyes or mucus membranes after applying product.
Cascara *Rhamnus purshiana* (dried bark)	Laxative	20-30 mg Tablet cascaroside/d	Loss of electrolytes with chronic use; contraindicated if gastrointestinal obstruction is present; do not use if pregnant or lactating.
Psyllium *Plantago psyllium, P. ovata P. spp (seed)*	Laxative	Varies; 12-40 g/d 1-3 teaspoons; 5-15 g soaked in water, taken with ample liquid (1-2 glasses of water)	Contraindicated if gastrointestinal obstruction is present; allergic reactions (rare).
Senna *Cassia spp* (leaflets)	Laxative	Often taken as an infusion or tea; 0-5-2 g steeped in hot water for 10 minutes	Diarrhea, nausea; avoid chronic use
Slippery elm *Ulmus fulva* (inner bark)	Oral demulcent/agent that forms a soothing, protective film on a mucous membrane surface	No specified dosage	No adverse warmings; available in throat lozenges and teas.
Witch hazel *Hamamelis virginiana* (leaves, bark)	Astringent	External-diluted 1 ;3 with water or 1:3 as stem distillate; ointment/gel: 5 g witch hazel in 100 g ointment base	Stomach irritation, liver damage if taken internally (rare)

in sports, the efforts by sports organizations to create awareness and the rigorous detection in athletes' samples [7]. The athletic trainer and sports medical advisers have the role to play as educational resource for athletes wishing to learn and be sensitized about herbal supplements. Herbal products are widely commercialized to both competitive and recreational athletes with the promotional factor of high performance and the improvement of health and wellness [8-12].

Regulation of herbal and food supplement in sports

International considerations of herbal products and food supplements

Reports indicate that there is limited number of herbs with FDA approval, and considerable information on the use and dosage of herbals comes from European guidelines [4]. These guidelines vary considerably from one country to the next and often rely on the historical use of an herbal product. Substances are often accepted under the anecdotal evidence of reasonable certainty that they have a long history of use. This philosophy is similar to the World Health Organization's Guidelines for the Assessment of Herbal Medicines, which state that a substance's historical use is a valid way to document safety and efficacy in the absence of scientific evidence to the contrary [13]. A long history of use may allow for safety information to be gathered; however, it may do little to assess efficacy. The most often cited European guidelines are those of the German Commission E. From 1978, the German Commission E has reviewed clinical literature (including clinical trials and case studies) on more than 1400 herbal drugs [2,4]. The commission has produced more than 300 monographs on common herbal remedies. However, these monographs need to be used with caution given their reliance on historical bibliographic information that may or may not include data gathered from clinical trials. Athletic trainers must also be aware of the availability of Chinese herbal preparations and Ayurvedic herbal products. Ayurvedic herbs are used in the Ayurveda medical system that is common in India. Currently, about 300 herbs are used in general practice in traditional Chinese medicine. Often these herbs are sold in preparations that contain multiple herbs. For example, Chinese black balls contain up to 20 different herbs and are used to treat everything from arthritis to asthma [14]. Both Chinese and Ayurvedic products are largely unregulated, and some do not list ingredients in English which poses a major problem of detecting some possible drug-herbal interactions and early signal of the composition of the ingredients in the products [15]. The concerns for athletes range from positive drug testing to the risk of toxicity due to unknown ingredients.

Food and drug administration

The regulation of herbal products is very complex at a global scale as different countries have different policies towards the use of these products, especially in sport. There is therefore a confusing report of public safety issues, diversified international guidelines, persuasive advertisement, and partisan politics. In the US for example, the regulation of drugs, food, and cosmetics is the role of the FDA, whose objective is to assure the public of safety and effective product use. In the past five decades, the FDA required that all drugs be evaluated for safety and efficacy [8]. To avoid the burden of proof associated with FDA approval, herbal manufacturers began to label herbs as "foods" and commercialize them in health food stores. The FDA maintains a list of products that are "generally recognized as Safe" (GRAS), of which more than 250 herbs appear on the list, but these are herbs used for food flavoring and not for medicinal purposes [9]. At the moment, only a few of herbs have been shown to be safe and effective based on a 1990 FDA review of over-the counter drugs as indicated in (Table 1). It is estimated that more than 1400 herbs are commonly sold and promoted for medicinal uses worldwide [2-4,9]. Historically some manufacturers have been reluctant to file for FDA approval of herbal products due to the costs associated with drug research. Furthermore, herbs reviewed by the FDA have only been examined within a very narrow definition of medicinal actions [9]. This has kept the public largely unaware of which products were safe, effective, or both safe and effective [10]. In 1993, the FDA widely communicated an advance notice of proposed guide lines that addressed the herbal and supplement industry. The report discussed instances of herb-related deaths and concerns about toxicities [11].

The consensus in Washington was that stricter regulation was necessary to sensitize the public on the health concern of unapproved herbal product consumption [11]. This guideline created more conflict and an unanticipated public and political backlash from consumers who thought that their access to herbals and supplements would be

taken away. Companies cannot make claims on an herb's ability to cure a disease, but they may make claims about how a supplement affects the "structure" and "function" of the body. This nebulous language has not helped to clear the confusion surrounding the herbal industry. For example, a herb could not be claimed to cure inflammation but could be claimed to promote healthy joints (structure and function) [12]. Manufacturers can make structure and function claims as long as they provide a disclaimer stating that their products have not been reviewed by the FDA and are not intended to be used as drugs [6,13]. Under the current legislation, supplement makers do not have to prove a product is safe; the FDA has the burden of proving a product is unsafe. The FDA can only take action if a product is found to present a significant or unreasonable risk of illness or injury. Further confounding the herbal landscape are studies that show consumers tend to believe that products sold in a pill form have been reviewed for safety by the FDA, despite required label disclaimers [11,12].

Risk Factors Associated With Herbal Products

Concentration and purity

The risks associated with the use of herbal remedies and supplements can range from minor skin irritations to death. Determining the safety and efficacy of herbal products continues to be a challenge because the FDA, herbal supplement manufacturers, and herbal experts have not come to an agreement on how to interpret the varying evidence available for many types of herbal products [15]. Due to the limited regulation of herbal products, athletes are often unable to tell how much of the herb or which part of the herb is contained within a given product [1,5]. Data mining information and the media have reported concerns with herbal products in many countries consumed by the population and sports men in particular. In 1995, Consumer Reports [1], tested 10 brands of ginseng and found substantial variations in concentration among brands. Furthermore, in March 1998, the Good Housekeeping Institute tested 9 brands of St. John's wort and found a significant variation in the amount of active ingredient [13]. The Los Angeles Times also tested St. John's wort in 1998 and found that 7 of the 10 brands tested were low in the amount of purported active ingredient [1,16]. The herbal activity to create a physiologic response depends upon the availability of a specific bioactive metabolites and concentration or dose response dependent [17]. The variability of these active ingredients is of concern because the most profound risks of herbal product use are toxicity and adverse reactions, herb-drug interactions, and adulteration of herbal products.

Toxicities and Adverse reactions of herbal products

Many cases of toxicity have been associated with the use of herbal products [16,17]. These effects range from minor adverse reactions to serious physical disabilities and death. Adverse reactions have been reported in athletic training settings, such as the report of Myers et al [18] on syncope and atypical chest pain in an intercollegiate wrestler after ingestion of an over-the counter metabolic stimulant containing Chinese herbal extracts [19-20]. This particular stimulant (Ripped Fuel, Twinlab Inc, Ronkonkoma, NY) contained ephedrine and caffeine. The stimulant effects were compounded by the athlete's aggressive weight-loss techniques. Other reports were made that described a 19-year-old female soccer player with an episode of syncope and tachycardia after ingestion of an over-the-counter stimulant containing ma huang, guarana, and caffeine [21]. This athlete had also been severely restricting calories to lose weight. These cases illustrate a common problem with athletes taking products that are marketed as "metabolism boosters" that contain "natural" herbal ingredients [7,22]. The herb ma huang and all ephedrine alkaloids have received considerable attention from the FDA. More than 15 deaths have been linked to the use of ephedrine alkaloid products [23]. In 1996, the FDA issued a warning to consumers to avoid nutritional supplements containing ephedrine. In 1997, the FDA proposed the use of warning labels addressing the adverse effects of ephedrine, banning products containing more than 8 mg per serving, and eliminating products containing combinations of ephedrine and caffeine [24].

An FDA report identified 76 botanicals known or suspected of containing aristolochic acid and 92 botanicals believed to be adulterated with aristolochic acid. Products containing a large amount of this substance may produce rapid-onset toxicity. However, the effects of long-term use are unknown [25]. The first indication of adverse effects may be irreversible, such as renal failure [26-55], and toxicity and adverse effects of some common herbs that athletes may come in contact with or may already be using are outlined in Table 2.

These herbal products are categorized as stimulants or energy boosters, weight-control agents, pain-control (ie, analgesics) and wound-healing agents, anti-inflammatories, antidepressants, and sleep aids. Some herbal drugs on the market have been found to be relatively safe and free of serious adverse effects when taken in specific dosages (Table 3). These herbs have undergone clinical trials, have been reviewed by German Commission E, or have a history of safe consumption. Despite safety claims, patients and health care providers should be aware that abuse of dosages and problems with adulteration may render an otherwise safe herbal product dangerous. Ginseng, although considered by many sources to be relatively safe, had a high incidence of adverse effects in a 2-year study by Siegel [56]. The long-term use of ginseng has been associated with central nervous system excitation and arousal [57]. The long-term effects have been labeled ginseng abuse syndrome, as indicated in Table 3 [56,57].

The issue of herbal interaction is a challenge as patients often neglect to mention herbs when asked by their health care providers about medications taken on a regular basis because they (1) consider that herbs are natural, (2) are embarrassed to give the reason they are taking the herb, or (3) feel their physician will not approve of their herbal use [52-69]. However, not informing health care providers about herbal use places patients at risk because of the possible interactions between drugs and herbs (Herbal-drug interaction) as indicated in Table 4.

Due to limited research showing which herb-drug combinations athletes are likely to consume, some examples have been shown from the literature of over-the-counter and prescription drugs that athletes may come in contact with or may already be using. The known effects of using prescription drugs and herbs in combination are that herbs can "mimic, magnify, or oppose the effect of the drugs [69,70]. Athletic trainers need to be sensitive, form a trusting relationship with athletes, and ask about the possible use of herbal products in a nonthreatening manner.

Product manufacturing

The DSHEA granted authority to the FDA to establish "good manufacturing practices" for herbal products [These regulations would govern the preparation, packing, and holding of dietary supplements under conditions that assure their safety. These regulations are to be modeled under guidelines currently in effect for the food industry. So far, the FDA has not fully implemented manufacturing guidelines for the herbal industry [70-99], and good manufacturing practices for ensuring purity and potency of products were a common theme during the June 1999 Dietary Supplement Stakeholder Meeting held

Table 2: Toxicity and adverse effects of common herbs [14].

Herb Name	Common Use	Toxicity/Adverse Effects	Supplements Containing Suspect Herbs
Stimulants/energy boosters Asian ginseng	Increase energy, improve mood, and improve resistance to infection	Insomnia, nervousness, irritability	
Ephedrine (ma huang)	Stimulant, appetite suppressant treatment of asthma, colds, flu, nasal congestion	Seizures, high blood pressure, cardiac arrhythmia and infarction, insomnia, psychosis, stroke, urine retention, uterine contractions.	Metabolife (Metabolife International, Inc, San Diego CA); Thermogenic Activator Plus (Rippedbody4less corp, Marina Del Rey, CA); Ripped Fuel (Twinlab Inc, Ronkonkoma, NY)
Ginseng	Stimulant	Sleeplessness, nervousness, hypertension togetherness, skin eruptions, edema, morning diarrhea	Metabolife
Khat	Stimulant	Deterioration of psychosis, weight loss, abdominal pain	
Guarana	Stimulant	Insomnia and agitation	Metabolife Thermogenic Activaor Plus; Herbalife Products (Herbalife International Inc, Century City, CA); Diet Fuel (Twinlab)
Weight Control Aristolochic acid	Weight control	Interstitial renal fibrosis and renal failure	
Sauropu androgynus	Weight control	Bronchiolitis obliterans	
Pain control/wound healing Comfrey	Internal and external wound healing	Can cause carcinoma of the liver and veno-occlusive disease	
Feverfew	Treatment of migraine headaches, anti-inflammatory	Increase heart rate, allergic reactions, mouth ulcers, headaches, gastric disturbances, post feverfew symptoms of aches, pain, and joint and muscle stiffness	
Germander	Choleric and antiseptic properties	Causes hepatotoxicity; more than 30 cases of acute liver failure, including 1 fatality	
Anti-inflammatory Evening primrose oil	Anti-inflammatory, sedative, anticoagulant, astringent	Gastrointestinal disturbances	
Flax	Anti-inflammatory	Diarrhea, nausea, flatulence	
Lobella	Aid for asthma and bronchitis	Respiratory depression, rapid heart rate, coma, death	
Antidepressants St. John's Wort	Alleviates depression and anxiety	Restlessness, fatigue, photosensitivity, constipation, dizziness, dry mouth	
Sleep aids Kava kava	Sedative, reduces stress	Gastrointestinal disturbances; temporary discoloration of skin, hair, hair, and nails; metabolic abnormalities	
Valerian root	Sleep aid	Decreases blood pressure, heart palpitations, upset stomach	

Table 3: Potentially Beneficial Herbs [5].

Herb Name	Safety/Efficacy	Recommended Dosage	Clinical Trials
Chamomile (*Matricaria chamomilla*)	Safe and effective	Infusion/tea: 3 g/150 mL water steeped for 10 minutes	In controlled trials, positive effects on wound healing, as a mild sedative, and in combination with other herbs as a treatment for infant colic
Echinacea (*Echinacea spp*)	Safe and effective	Varied; tincture: 30-60 drops, tid; pressed juice: 6-9 mL	Mixed results: beneficial in shortening duration of common colds but less effective in preventing colds
Feverfew (*Tanacetum parthenium*)	Safe and effective	50 mg-1.2 g/day (Leaf powder)	Mixed results, but clinical research tends to support feverfew as a prophylaxis agent for migraines.
Garlic (*Allium sativum*)	Safe and effective	Varied preparations; 4 g fresh garlic/day; 8 mg essential oil/day	Mild beneficial effect on serum liquids and reducing serum cholesterol, serum triglycerides and low-density lipoprotein cholesterol, and modest antihypertensive effect. Randomized, double-blind, placebo-controlled clinical trial: no change in cardiovascular risk factors compared with placebo in children who had familial hyperlipidemia
Ginger (*Zingiber officinale*)	Safe and effective	2-4 g taken with liquid	Mixed results: treatment of motion sickness and postsurgical nausea and vomiting; helpful in treating hyperemesis gravidarum (morning sickness)
Ginkgo (*Ginkgo biloba*)	Safe and effective	120 mg dried extract bid to tid	Controlled trials: positive results in the treatment of chronic cerebral insufficiency. Double-blind, placebo-controlled trials of patients who have memory loss: some improvement in memory. Randomized, controlled studies: promise in treating memory loss and psychopathologic conditions in Alzheimer disease and dementia. Controlled studies on intermittent claudication: favourable results. No studies have been done on pulmonary problems or attention deficit hyperactivity disorder.
Ginseng (*Panax ginseng*)	Generally deemed Safe and effective	Varied preparations, average daily dose is 1-2 g root/day	Clinical trials: ginseng improved mood, cognitive performance, and physical performance.
Saw palmetto (*Serenoa repens*)	Safe and effective	1-2 g/day	Randomized trials support the efficacy of saw palmetto in treating urinary flow in men with benign prostatic hyperplasia
Valerian (*Valeriana officinalis*)	Safe and effective	Varied preparations; 15 g/day; tea: 3-5 g/150 mL hot water, steeped for 10-15 minutes, bid or tid.	Randomized, double-blind, placebo-controlled studies: decreased sleep latency and improved sleep quality.

Table 4: Drug interactions with common herbs.

Drug Name	Common Use	Herbal Name	Common Use	Known Interactions
Anti-inflammatory Aspirin	Anti-inflammatory Analgesics Antipyretic Antirheumatic	*Ginkgo biloba*	Increase circulation, increase short-term memory	Spontaneous hyphema
Hydrocortisone	Anti-inflammatory	Licorice	Expectorant, antiulcer	Glycyrrhetinic acid (an acid in topical anti-inflammatories) potentiates cutaneous vasoconstrictor response
Oral and topical corticosteroids	Anti-inflammatory	Licorice	Expectorant, antiulcer	Potentiates corticosteroids
Oral contraceptives combined oral contraceptive	Birth Control	St. John's wort	Alleviate depression and anxiety	Breakthrough bleeding
Oral contraceptives	Birth control	Licorice	Expectorant, antiulcer	Hypertension, Edema, Hypokalemia
Antidepressants Antidepressants	Antidepressant	Panax ginseng	Stimulant	Induces mania in depressed patients
Lithium	Manic depression	Psyllium	Reduce cholesterol	Decrease Lithium concentrations
Paroxetine	Antidepressant	St. John's wort	Alleviate depression and anxiety	Lethargy, incoherence
Pheneizine	Monoamine oxidase inhibitor, antidepressant	Ginseng	Stimulant	Headache, tremor, mania
Serotonin-reuptake inhibitors	Antidepressant	St. John's wort	Alleviate depression and anxiety	Mild serotonin syndrome, decreased bioavailability of digoxin, theophylline, cyclosporin, phenprocoumon
Trazodone, sertraline, and mefazodone	Antidepressant; obsessive/ compulsive disorders	St. John's wort	Alleviate depression and anxiety	Mild serotonin syndrome
Bronchodilator Theophylline	Bronchodilator	St. John's wort	Alleviate depression and anxiety	Decreased theophylline concentration

by the FDA's Center for Food Safety and Applied Nutrition [99]. This meeting included participants from the different sectors of the herbal industry and at the center of the manufacturing discussion was the idea of herbal plant standardization. Setting standards for supplements would mean that a specified amount of the herb is detectable, measurable, and known to have a biological response in the body [100]. This desired consistency does not currently exist and therefore, resolving this problem of standardizing and regulating herbal supplements is difficult. Differences in soil quality, percentage of herb used, harvest time, climate changes, growing seasons, and exposure to light represent some factors that may affect herb quality [100]. While the need to improve manufacturing practices is widely accepted, lack of agreement on standards and rules for enforcement has slowed down the bureaucratic rule-making process [99]. The herbal industry has taken the responsibility to police itself with regard to assuring product quality. The National Nutritional Foods Association randomly tests products produced by its members. The Association also plans to begin certification of factories every 3 years using the same good manufacturing processes proposed by the FDA, although manufacturers are not required to belong to this organization. In addition to the National Nutritional Foods Association, the United States Pharmacopeia (USP) sets standards for pharmaceuticals, vitamins, and minerals. The USP, a private, nonprofit organization, has begun to produce monographs about herbs that sum up evidence of effectiveness and detail standards for quality, strength, and purity of the final product [1,99]. Adoption of these standards is voluntary, and manufacturers claiming to meet them are not checked except in response to complaints.

Product Adulteration

Despite attempts to improve manufacturing processes, reports on product adulteration, contamination, or both are less indicated in the literature due to lesser studies [24,46,53]. Adulteration cases often include Ayurvedic and Chinese herbal medicines with multiple bioactive compounds. These products have been contaminated with lead, arsenic, and other highly toxic substances. The British National Poisons Information Service identified herbal preparations containing toxic levels of lead, zinc, mercury, arsenic, aluminum, and tin. The individuals who had ingested the herbals products are elevated by 2 to 10 times the upper limit of normal physiologic values [83]. One report of herbal product adulteration showed more than 48 cases of renal poisoning when the patients thought they were taking a local herbal plant fang ji. When in reality, patients were taking guang fang ji. The problem seems to lie in the similarity of the names in Chinese [70]. Digitalis can cause nausea, vomiting, and irregular heartbeats [73]. Many studies have raised doubts on the purity and content of herbal products. Bahrke and Morgan [55] reported on quantitative differences in individual and total ginsenosides within herbal products. The factors affecting these differences were species variations, growing environment, soil and fertility conditions, age of the roots, different parts of the plant, and extraction methods [98]. These factors may also play a role in the physiologic effects of ginseng, which might explain the reported adverse effects [55]. Many of the problems associated with the adulteration, variable purity, and potency of herbs could be addressed with improved manufacturing and quality standards.

Plant Metabolites

Plants have been shown to provide several essentials metabolites such as carbohydrates, lipids, and nucleic acids and numbers of secondary metabolites such as anticarcinogenic, antithrombotic, cardioprotective, and vasodilatory [5]. These biological properties are mediated by their antioxidant characteristics and redox potentials. Plant metabolites play an important role in stabilizing oxidative damage by neutralizing free radical, oxygen scavenging, or decomposing peroxides [6]. So far, several studies have highlighted the role of herbal supplements in reducing exercise induced oxidative stress in athletes [6,7]. In some athletes reducing oxidative stress can enhance muscle recovery and energy maintenance during intensive exercises [3,8,9].

Herbal products such as ginseng, caffeine, and ephedrine are rich in antioxidant bioactive compounds and as such are the best candidate to enhance muscle performances. Other plants such as *Tribulus terrestris*, *Ginkgo biloba*, Rhodiolarosea, *Cordyceps sinensis* have been used for muscle growth and strength in sport men [3,8,9], while others [10-13] have demonstrated no effect on muscle performances. Heterogeneous clinical outcomes observed in previous studies are coming from different factors such as type of the plant, the geographic location from which the plant was gathered, and the method of extraction used. Furthermore, most of previous research highlighted the efficacy of herbal supplements without precise information about the potential risk or negative side effect in athletes [14]. Although the commercialization of natural supplements has contributed to improve health and physical performance, it should also be noted that some plants extracts may be composed of doping substances as well as some products based on herbal extracts may be contaminated or adulterated by agents prohibited in sport [15]. Therefore, the real beneficial effects of herbal products on sport performance still remain non-conclusive [l]. In this review, we have identified the most used plants as supplement in sports and have these products into the following categories: Ginseng, herbal sources of caffeine and ephedrine and other purported herbal ergogenic plants such as *Tribulus terrestris, Ginkgo biloba*, and *Rhodiola rosea.*

Selected Herbal Plants for doping in Sports

Guarana (*Paullinia cupana*)

Guarana, also known as Guarana Gum, Guarana Seed, Zoom Cocoa and Brazilian Cocoa, is native from the Amazon region. The active compounds in Guarana are the alkaloids: Caffeine, Theophylline, Theobromine, Tannins and Saponins [40]. According to Natural Medicines Database [48], Guarana contains higher amount of caffeine than most plants with up to 3.6% to 5.8% of caffeine compared to 1% to 2% in coffee. Guarana has been shown to activate central nervous system by increasing mental vigilance, fatigue resistance and improvement of body weight [49]. The seeds are mostly used to treat headaches, paralysis, urinary tract irritation, and diarrhea [26]. They are known to interact with many types of supplements and medicaments such as products that contain caffeine, monoamine oxidase inhibitors, adenosine, clozapine, lithium, and acetaminophen [50]. Guarana may have serious side effects for some individuals, like appetite suppressant effect related to the caffeine content. The side effects of this plant such as anxiety, insomnia, rapid heartbeat and stomach upset are linked to its caffeine content. The guarana fruit and chemical structure theophylline are shown in Figure 1.

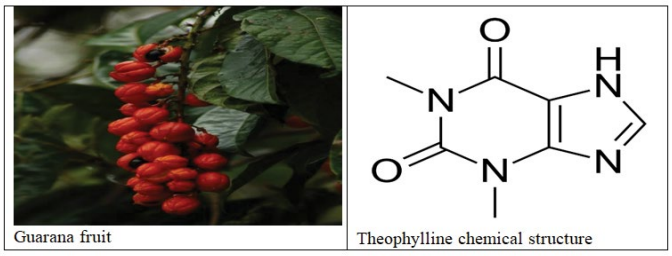


Figure 1: Guarana fruit and chemical structure theophylline.

Green tea

Green tea (*Camilla sinensis*) extract is one of the important herbal supplements used to prevent weight gain [51] and stimulate nervous system [52]. It contains high concentration of caffeine and Catechin Polyphenols, Theobromine and Theophylline rich with antioxidant properties, increase energy expenditure by stimulating brown adipose tissue thermogenesis [52]. It has been shown that combining of green tea with caffeine (50 mg caffeine and 90 mg of Epigallo catechin Gallate for 3 times per day) significantly increases 24-h energy expenditure and fat metabolism in active individuals. The green tea and chemical structure of polyphenol epigallocatechin gallate is illustrated in Figure 2.

Green tea extracts (GTE) supplementation has been found to increase endurance capacity, improve the antioxidant defense system, and muscle lipid oxidation in healthy or diabetic individuals [53]. In addition, it increases plasma glycerol and epinephrine levels following sprint training in trained and untrained men [54]. In addition, GTE reduces oxidative DNA damage induced by exercise after 14-day in untrained obese men [55] and after 4 weeks in sprinters [56]. However, reports have shown no changes in antioxidant enzyme or sprint performances after GTE supplementation in sprinters [56]. There is a gap of information on the effects of long term GTE supplementation on antioxidant biomarkers, plasma muscle damage parameters in trained individual and most studies using GTE supplementation did not assess the amount of other active components in green tea which would underestimate or overestimate the role of GTE on oxidative stress balance [56].

Ginkgo biloba

Ginkgo biloba (GB) is one of the most popular herbs widely distributed in Asia. The active bioactive compounds are the Flavonoids [101] and Terpenoids [102]. Their flavonoids content promotes the blood circulation and in particular cerebral blood circulation. It is used in disorders caused by a reduction in blood flow such as Alzheimer's disease, memory loss, migraines and headaches and Parkinson's disease. They have been found to activate the release of endothelium-

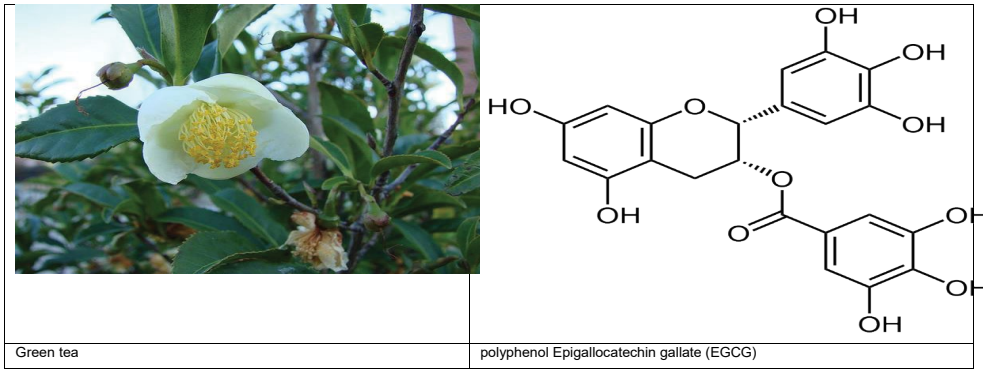


Figure 2: Green tea and chemical structure of polyphenol epigallocatechin gallate.

derived relaxing factor, which may enhance muscle tissue blood flow through improved microcirculation [103]. Figure 3 shows *Gingko biloba* and related chemical structures salicyclic acid and oleandrin

The leaf of *Ginkgo biloba* shows high concentration of flavonoids with important antioxidant properties. Leaf extracts from GB has been used for natural commercial products such as (i.e., EGb 761®, Tanakan® or Tebonin®) of which some of the products such as EGb 761 are not yet approved by FDA in U.S, but still available only by prescription in Europe.

Ginkgo biloba in sports enhances endurance performance (longer walking distance) in patients with peripheral arterial disease (PAD). However other studies showed that GB supplementation (24 weeks: 2 × 120 mg/day tablets) has no effect on walking economy or walking performance in patients with PAD [104, 105]. It is also reported that 7-week of GB ingestion combined with RR improve the endurance performance (higher VO_{2max}) and time to exhaustion in healthy young athletes [106]. Recently, numerous researches observed amelioration in cognitive performance especially in elderly with dementia syndrome [107,108]. Despite its beneficial effects, GB is considered as safe herb only when taken by healthy adults by mouth and at limited doses and it can reduce blood glucose. GB needs to be taken with precaution especially by people with diabetes or hypoglycemia or following anaerobic exercises [109].

Theobromine and theophylline

Theobromine and Theophylline are common in many plants like kola and tea. In sport, athletes used the Chocolate and Cocoa form as a principal source of alkaloids [35]. It is reported the presence of higher antioxidant properties with no immune function alterations following Cocoa ingestion in healthy trained and untrained individuals. So far, there are few studies that have shown the effect of definite doses of these alkaloids in athlete, due mainly to the incomplete data related to its compounds. Figure 4 and Figure 5 show the cocoa plant and cocoa seeds that contains theobromine and theophylline (Cocoa chemical structure of theobromine and theophylline).

Plant derived-Ephedrine

Ephedrine is a central nervous (CNS) stimulant often used to prevent low blood pressure during anesthesia [3,5]. It has also been used for asthma, narcolepsy, and obesity but is not the preferred treatment [6]. It is of unclear benefit in nasal congestion [6]. It can be taken by mouth or by injection into a muscle, vein, or just under the skin [6]. Onset with intravenous use is fast, while injection into a muscle can take 20 minutes, and by mouth can take an hour for effect [6]. When given by injection it lasts about an hour and when taken by mouth it can last up to four hours [6].

Ephedrine is an alkaloid with ergogenic properties that can be found in plants of the Ephedra type. The Ephedrine is a potent pharmacologic agent with various peripheral and central effects. Numerous studies have found a link between Ephedrine ingestion and higher physical performances [3,61] and weight loss [62]. In fact, Ephedrine has been used as a medical drug and a stimulant to treat low blood pressure, urinary incontinence, narcolepsy and depression [63]. It is currently used as a treatment of bronchial asthma, nasal inflammation, and the common cold [64]. It also enhances aerobic capacity, reduces fatigue, increases alertness, and reaction time during exercise [65].

However, Ephedrine uses was usually combined with caffeine in major studies which limit his potential role compared to caffeine [3,9]. In previous studies, different dose of caffeine (≤300 mg) and Ephedrine (≤70 mg) were used in recreational, runners and resistance trained

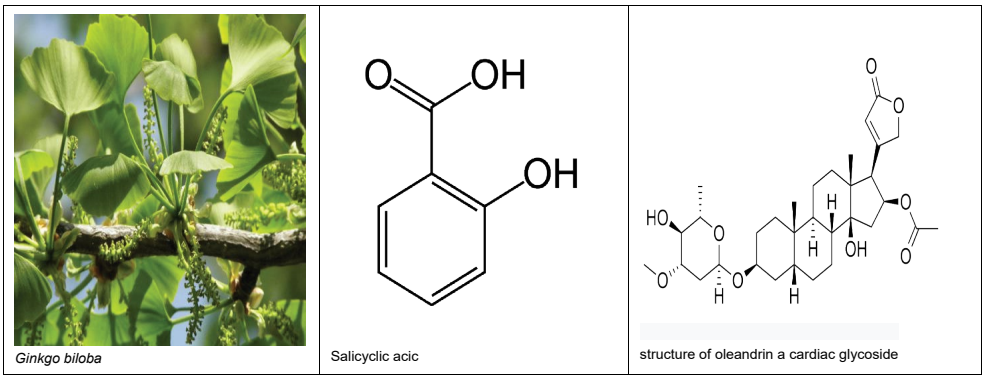


Figure 3: *Gingko biloba* and related chemical structures salicyclic acid and oleandrin.

Figure 4: Cocoa plant and cocoa seeds.

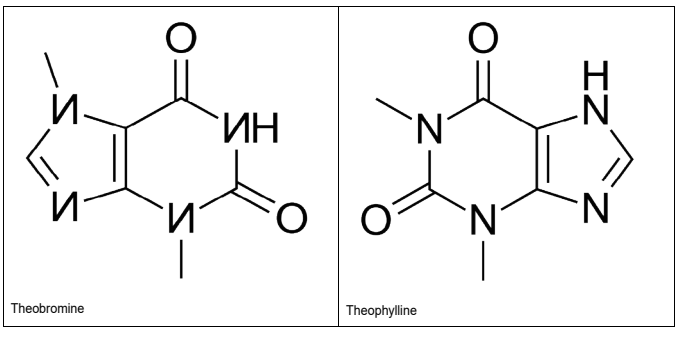


Figure 5: Cocoa chemical structure of theobromine and theophylline.

athletes and showed decrease in running time and increase in muscle performances. Some studies [66] found that combining ephedrine and caffeine (oral ingestion) improves weight loss in adolescents, with mild and temporary negative side effects. In some other few studies, when Ephedrine was taken alone, there was no improvement in physical performance [67]. It should be emphasized that both ephedrine and its derivatives (Cathine, Methyl ephedrine, Pseudo ephedrine) are considered to be doping substances at higher doses and would allow several harmful effects on body's health [68,69]. They are prohibited by the World Anti-Doping Agency (WADA) [46] in sports competition. Uses of ephedrine have been linked also to sleeping disorder, anxiety, headache, hallucinations, high blood pressure, fast heart rate, loss of appetite, and inability to urinate in several cases [70,71]. Figure 6 shows plant derived ephedrine and ephedrine alkaloid structure.

Ginseng

Ginseng is one of the most popular herbal dietary supplements and is the most widely studied herb with respect to physical performance [9]. Ginseng belongs to the Araliaceae family, with many species widely distributed globally such as Asian ginseng, Korean ginseng, Chinese ginseng (*Panax ginseng*), American ginseng, Canadian ginseng (*Panax quinquefolius*) and Siberian ginseng (*Eleutherococcus senticosus*) [9]. Numerous Asian countries, particularly China and Korea use ginseng in the dietary and medicinal domain, whilst the Panax ginseng preparations have been elaborated in human clinical trials [9] such as for anti-inflammatory, antioxidant, brain function stimulant, anabolic and an immunostimulant, and an endurance performance enhancer [23,52]. The ginseng species contains numerous important compounds such as the vitamins (A, B, C and E), minerals (iron, magnesium, potassium and phosphorus), fibers, proteins, saponins and Ginsenosides the main active constituents in Panax herbs. This component has been shown to reduce mental stress, improve immune function, and stabilizes blood pressure [15]. Ginseng roots and complete plant is illustrated in Figure 7 and Figure 8: Chemical structures of three ginseng saponin types: (a) protopanaxadiol type (PPD); (b) protopanaxatriol type (PPT); and (c) oleanolic acid type.

Siberian ginseng contains unique steroidal saponins named Eleutherosides which appears to be structurally similar to Panax ginsenosides [16] and contains phenolics and polysaccharides. Panax have been demonstrated to have ergogenic effects [17]. Small amount ≤ 200 mg/day of Panax ginseng (root powder or root extract with standardized Ginsenoside content), allows greater improvements in cognitive performance and anaerobic performance in untrained young or older subjects [8,9].

Like most supplements, ginseng has side effects, some of which are important depending on the dose and one's metabolism. The use of ginseng has been shown to cause diarrhea, insomnia, headaches, rapid heartbeat, blood pressure fluctuations, and can cause digestive disorders. Women may experience additional side effects, such as vaginal bleeding and breast tenderness [15]. Most of these side effects are serious enough to warrant stopping taking ginseng in breast cancer patient. Ginseng can interfere with various medications, such as insulin, digoxin, anticoagulants, and monoamine oxidase inhibitors. Moreover, it can be contraindicated in patient with high blood pressure [26]. As such, ginseng has a major limitation in healthy population. It has been documented that ginseng should be avoided by the energetic, nervous, tense, hysteric, or schizophrenic individuals, and should not be taken in combination with other stimulants, drugs or during hormones treatment. Hence, further research is needed to clarify the effects of major compound of ginseng [27].

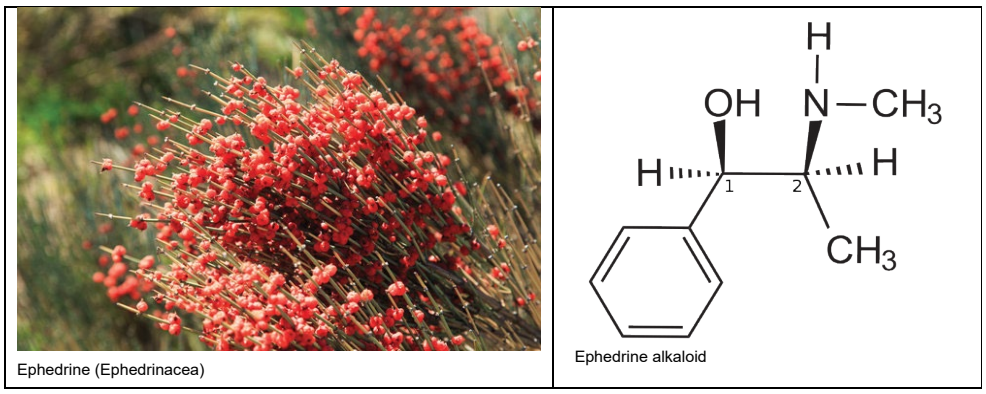


Figure 6: Plant derived ephedrine and ephedrine alkaloid structure.

Figure 7: Ginseng roots and whole plant.

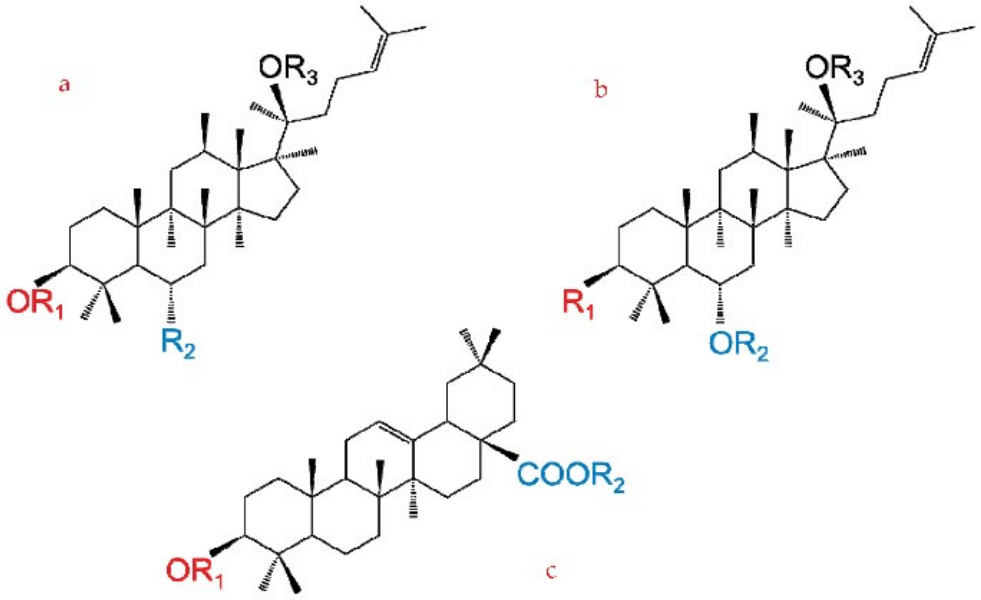


Figure 8: Chemical structures of three ginseng saponin types: (a) protopanaxadiol type (PPD); (b) protopanaxatriol type (PPT); and (c) oleanolic acid type.

Alkaloids caffeine

Caffeine is a natural compound found in plant species growing in the tropical or Sub-tropical regions of the world. This compound decreases the risk of degenerative brain diseases caused by aging (cognitive decline, dementia) and permits reducing the risk of Parkinson's disease. Caffeine is an alkaloid that may be perceived to be ergogenic. Caffeine may offer greater benefits on both endurance and anaerobic performances [32,33]. A small quantity of caffeine (≈2 to 9 mg/kg body mass) taken at least 1-h prior to exercise or competition stimulates greater improvements in some measures of strength, and increases serum catecholamine levels and immune responses in runner and cyclist [35]. Higher blood catecholamines have been found to increase anaerobic performances (sprint performances) and aerobic performances (VO2max) in healthy young and middle-aged individuals [35,36]. Caffeine supplementation can also improve performance at different exercise intensities levels [37] as well as mental vigilance and humor [8]. Observation have shown a significant increase in endurance running performance after ingestion of 9 mg/kg body mass of caffeine 1-h prior to exercise [38]. Investigating the effects of caffeine ingestion on sprint performance in trained and untrained swimmers revealed that, subjects' swimming velocity and maximal blood lactate concentration was significantly improved in both untrained and trained subjects after caffeine ingestion [39]. Other study found that ingestion of 1-2 mg/kg caffeine at breakfast decreases reaction time during exercise and improves mental alertness [40]. Some evidence suggested that caffeine ergogenic effect is due to its antioxidant property [41] and its effect on free fatty acids (FFA) [42]. Other studies found an increase in endurance performance and higher amount of plasma FFA following caffeine supplementation (5 mg/kg body weight) [43].

Coffea arabica

Coffea arabica is a species of Coffea originally indigenous to the forests of the south-western highlands of peninsula in Northeast Africa. Coffea may have similar effects to caffeine's, as coffea is a complex mixture resulting from a hot-water extract of roasted coffee beans. Although many biological mechanisms are attributed to caffeine's action as an adenosine antagonist which increases many neurotransmitter activities [32]. Rafiul Haque et al. [47] found that *Coffea arabica* seeds have stimulatory effect on cellular immune function in mice. Figure 9, Figure 10. Show coffee fruit plant and caffeine alkaloid chemical structure.

Salix alba

Salix alba (White Willow) is a tree of the Salicaceae family native to Europe and western and central Asia. It contains Salicin, which is converted to acetylsalicylic acid inside intestine. The willow bark has been used to treat pain, inflammation, osteoarthritis, aches and to reduce fevers [109-129]. In fact, short period of willow bark supplement (240 mg salicin/day for 2-week) decreases joint pain in patients with osteoarthritis [130], while longer period (6-week) does not seem to improve this symptom [131]. In addition, oral administration of 120 mg or 240 mg salicin for 4-week reduces back pain in patient with low back pain [132]. In sport, this extract has been used to treat musculoskeletal and joint-related conditions (injuries, inflammation) [133]. However, no studies were conducted to investigate the ergogenic effect of this herb on muscle performance in athletes, which present a limitation of his actual use in sports field. Shara and Stohs [129] suggested that adverse effects appear to be minor when compared to non-steroidal antiinflammatory drugs such as aspirin. Figure 11 shows *Salix alba* plant that contains salicin.

Ginger

Ginger is found in the tropical rainforest in Southern Asia and it includes alkaloids. Ginger (Zingiberofficinale Roscoe; Zingiberaceae) is a flowering plant that has been used in medicine for decades. Ginger has few negative side effects and it is listed in the FDA's "safe" list [71]. Ginger has been shown to have anti-inflammatory effect in vitro studies [35] which may be due to Gingerols, Paradols, Shogaols, their congeners, or other compounds. Till today, few studies have demonstrated analgesic effect of Ginger and fatigue resistance in athletes, while few other studies have not found any effect on body

Figure 9: Coffee fruits.

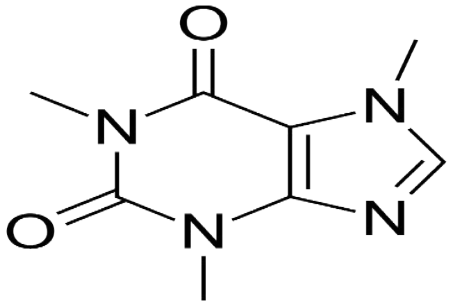


Figure 10: Caffeine alkaloid chemical structure.

Figure 11: *Salix alba* plant that contains salicin.

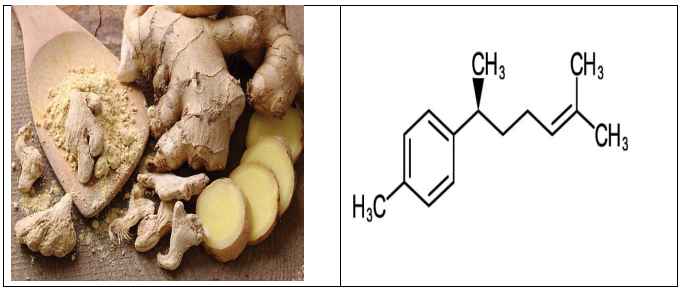


Figure 12: Ginger rhizome (Zingiber officinale) and Structure of zingiberene.

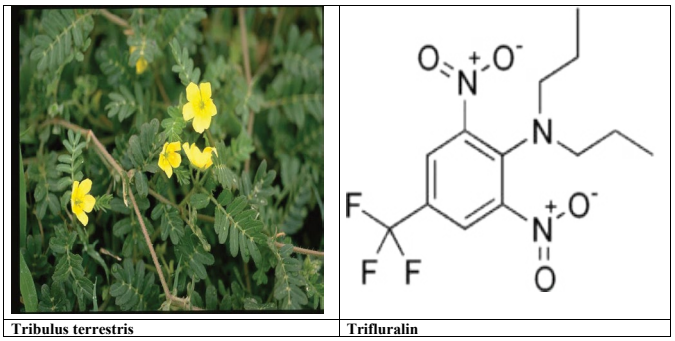


Figure 13: Tribulus terrestris and chemical structure Trifluralin.

composition, metabolic rate, oxygen consumption and muscle strength in athletes [72]. Figure 12 shows ginger rhizome (*Zingiber officinale*) and Structure of zingiberene, Nakhostin-Roohi et al. [73] explored the effect of 150 mg curcumin (Curcuma longa) supplementation immediately after intensive eccentric squat exercise in healthy young males. They found decreased levels of serum inflammation biomarkers (creatine kinase (CK), alanine aminotransferase (ALT), and aspartate aminotransferase (AST)) in experimental group compared with placebo group. Curcumin is a diaryl heptanoid, belonging to the group of curcuminoids and a member of the ginger family (Zingiberaceae) and composed mainly by phenols. About harmful effect, it was demonstrated that high doses of curcumin (> 8 g/day for 3–4 months) had no toxic effect in most cancer patients, while few number of patients had nausea or diarrhea [74].

Other plant with ergogenic properties

Tribulus terrestris

Extracts of Tribulus Terrestris (TT), a flowering plant distributed in the world, have been used to treat urinary tract infections, urolithiasis, dysmenorrhea, edema, hypertension, and hypercholesterolemia [3]. The most important chemical compositions of this plant are steroids; Saponins like Dioscine, Diosgenin, and the Protodioscin. These elements can have beneficial effects on libido and physical fitness. It also contains Phytosterols, in particular Beta-Sistosterols, which is beneficial for the prostate function, the urinary system and the cardiovascular system. In sports, plant gained wide recognition when medal-winning Bulgarian athletes from the 1996 Summer Olympics in Atlanta gave credit to TT for their success. Recent scientific studies found that *Tribulus terrestris* extract (TTE) improves testosterone production in healthy male [75,76]. Ivanova et al. [75] found that well-trained athletes and weightlifters used TTE supplementation to enhance production of luteinizing hormone (LH) and muscle growth. By increasing testosterone, reducing inflammation and oxidative damage in muscle, TT appears to be a potent performance enhancer [76]. TT is considered to be a safe alternative for the treatment of several diseases such as cardiovascular and Hypoactive sexual desire disorder (HSDD) in postmenopausal women [76]. Other studies have shown that TT supplementation (3.2 mg/kg body mass) has no effects on body composition and maximal strength (5-weeks: 450 mg of a TTE) [77], muscular endurance in resistance-trained men [7], testosterone levels in response to short period (5 day: 750 mg/day) or moderate long period (4-weeks: 10 or 20 mg/kg body mass) [78,79] in trained individuals. Figure 13 Tribulus terrestris and chemical structure Trifluralin.

Rhodiola rosea

Rhodiola Rosea (RR) is a popular herb used in traditional medicine

in Europe and Asia. RR, also known as the Pink Orpine, or Lignum Rhodium belongs to the Crassulaceae family. It is found in Scandinavia, Central Asia or the Arctic, France especially in the Pyrenees and the Alps. The most used part in this plant is the root. RR is composed by Rosine Rosarines, Rosin, Tyrosol, Rosiridin, Tannins and Polyphenols. The most important compounds are Salidroside and Rosavin [85]. It contains also minerals, vitamins, gallic acid and chlorogenic acid as well as antioxidants that have an effective action to fight the aging of the skin. RR has been used to treat stress and anxiety syndrome, prevent high altitude sickness, and stimulate the nervous system. These benefits are due to natural components of the root that would activate the production of four molecules: norepinephrine, serotonin, dopamine and acetylcholine. These molecules act directly on the cerebral cortex and increase attention, memory, concentration and intellectual capacity, increase fatigue resistance, and physical performance [85].

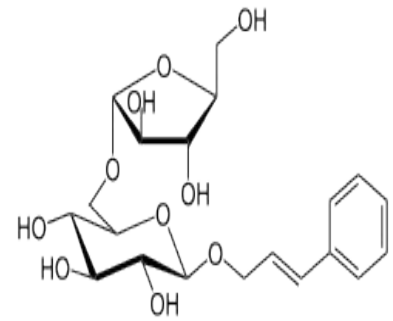
In addition, recent data reported numerous benefits of RR characterized by antioxidant properties and adaptogenic effects especially for weakness syndrome [85]. Walpurgis et al. [86] reported that supplements of root or rhizome extracts of RR were found to contain significant amounts of the endogenous Steroids 4-androstene-3,17-dione and Dehydroepiandrosterone (DHEA) and the Pseudoendogenous Steroid, 1,4-androstadiene-3,17-dione. However, reports documenting the occurrence of anabolic androgenic steroids are scarce. Figure 14 shows the. *Rhodioala rosea* plant and the chemical structure rosarin.

Most of previous effects were attributed to the plant component such as phenolics (Salidrosides, p-Tyrosol, and Glycosides like Rosavins) which are potential antioxidant elements [85]. The study of DeBock et al. [87] found that the consumption of RR (200 mg/day) improved time to exhaustion by 3% on a cycle ergometer, but demonstrated no significant effect following 4 weeks of supplementation and no effect on maximal strength or reaction time. Also, Parisi et al. [88] found that 4 weeks of RR supplementation could reduce lactate levels and muscle damage biomarkers in response to aerobic exercise in trained athletes. In addition, 3 mg/kg of RR ingestion has ability to decrease heart rate response to submaximal exercise and to lower the perception of effort during high-intensity endurance exercise in recreationally fit women [89].

Codyceps Sinensis

Natural *Cordyceps sinensis* (CS) is an entomopathogenic fungus found in the Asia mountain region. It is an ascomycete fungus that belongs to the family of Clavicipitaceae and to the order of the Hypocreales. It is efficient in the treatment of cholesterol and immune system disorder. The available synthetic version is CordyMax Cs-4. Chemical composition includes amino acids, Stearic Acid, D-Mannitol, Mycose, Ergosterol, Uracil, Adrenine, Adenosine Palmitic Acid, Cholesterol Palmitate and 5-alpha-8-alpha-epidioxy-5-alpha-ergosta-6,22-dien-3beta-ol. It has been used to improve renal function in patients with chronic allograft nephropathy [93]. CS regulate blood pressure by stimulating vessel dilation, activating the nitric oxide production, and increasing the oxygen exchanges through capillary barrier [94]. CS was found to induce higher endurance performance

Rhodiola rosea



Rosarin

Figure 14: Rhodioala rosea plant and the chemical structure rosarin.

Codyceps sinensis entomopathogenic fungus

Crocus sativum

Figure 15: *Cordyceps sinensis* entomopathogenic fungus and *Crocus sativum* plants.

[95]. Li et al. [96] found increase in hemoglobin levels following CS supplementation (5 days of 100–150 mg/kg) with greater aerobic capacity. CS extracts supplementation (powder form) appear to increase muscle fatigue resistance by enhancing lactic acid production, heart rate variability and blood pressure during maximal graded test in sedentary subjects [97]. In addition, a 240 mg of Cordyceps drink has been shown to improve cardiovascular responses in healthy runners [98]. Figure 15 illustrates *Cordyceps sinensis* entomopathogenic fungus and *Crocus sativum* plants.

Herbs marketed with limited scientific research

Several other plants such as Yohimbe, Spirulina (Arthrospira platensis and Arthrospira maxima), Moringa (Moringa oleifera), Bala (*Sida cordifolia*) and Camu (Camu Myrciariadubia) have been used as source of proteins, minerals, and vitamins ($VitB_{12}$ and Vit C). They were found to reduce body mass and increase endurance performance in runners and bodybuilders. Some of these plants have shown greater antioxidant capacity (i.e. Myrciariadubia, Biostimine, extract from Aloe arborescens Mill) [134]. Other plants such as *Lignosus rhinocerotis* [135], *Citrus aurantium* [136,137] have been used in combination with exercise training and/or with caffeine to enhance performances of young athletes. They were also found to be effective in reducing muscle soreness but failed to demonstrate any improvements in anaerobic or aerobic performances. Lignosus Rhinoceros (medicinal mushroom) for example has been extensively used safely without specific side effect in human or animals, while extracts from Citrus Aurantium are believed to induce similar harmful side effect of Ephedra [138-142].

Saffron (*Crocus sativus* Linn)

Saffron is derived from the flower of *Crocus sativus* cultivated in Greece regions and its dried extract contains B vitamins, flavnoids and dietary minerals (mainly Magnesium, Calcium and Potassium). It contains several volatile and aroma-yielding compounds such as Terpenes, Terpene Alcohol, and their esters. C. *Sativus* have several beneficial effects such as antihypertensive, anticonvulsant, antitussive, antigenototoxic and cytotoxic effects, anxiolytic aphrodisiac, antioxidant, antidepressant, antinociceptive, anti-inflammatory, and relaxant activity. It has been shown to enhance memory and learning skills, and increases blood flow in choroid and retina.

Myrtus communis L

Myrtus comminus L. is a species found in the myrtaceae family, native to the Mediterranean basin. Many phenolic compounds were identified in *Myrtus communis* L. berry such us phenolic acids (gallic acid, caffeic acid, syringic acid, vanillic acid and ferulic acid), flavonoids (quercetin, myricetin) and hydrolyzable tannins (gallotannins). Myricetin and its glycoside derivatives are the major constituents of myrtle berries [143-145]. Myrtle fruits are a high in phenolic content, especially the anthocyanins. For this, it is among the fruits with the highest antioxidant activity [146]. In addition, Myrtle fruit was characterized by higher levels of Linoleic Acid as well as low and varied proportions of saturated acids [120,147].

Myrtus communis

Recent studies have demonstrated the benefits of myrtle fruit Figure 16 (*Myrtus communis* L) as a supplement in sport. In fact, Slimeni et al. [123,147] demonstrated that 4 weeks of myrtle fruit supplementation (3.4 mg/kg /day) may increase anaerobic performances, serum proteins and Iron and reduce triglycerides, in moderately trained athletes.

It has several properties such as antiseptic, astringent, carminative,

Figure 16*: Myrtus communis* L.

hair tonic, analgesic, cardiotonic, diuretic, anti-inflammatory, stomachic, nephroprotective, antidote, brain tonic and antidiabetic [52], but presents minor harmful effects such as diarrhea and nausea following ingestion of high doses (> 4 mg /day) [15,148].

Today, many athletes have turned to various dietetic interventions, including the use of natural products based on herbs and plants to avoid risk from synthetic drug [1,23,150]. However, it is imperative to have a comprehensive and extensive guide, which allows expert and athletes to understand beneficial and harmful effect of some product better.

Conclusions

Despite the increased tendency to seek natural therapies, athletes need to be aware that not all-natural products are safe. Herbalist tag medicinal plants miracle cure rather than compounds that work through simple biochemistry. Specific compounds trigger a specific physiologic effect to give an effect that can be toxic if too much of a product is used or if it is used in combination with other medications. Athletes are entitled to know that most herbs are not proven safe and effective under current FDA standards. In addition, athletes may be unaware that the big publicity surrounding herbal products often contains untested claims, with proof of safety mostly of anecdotal evidence. If an athlete wishes to take an herbal supplement, he or she should use a standardized product. Products should have the scientific name and quantity of the botanical clearly identified on the label. The name and address of the manufacturer, lot number, and expiration date should be clearly marked. Given the risks of toxicity and drug interaction, questions regarding the use of herbal supplements are essential when a health care provider takes a complete history. Athletes should consult a physician about potential drug before taking an herbal supplement. They should be advised to stop taking the herb immediately if adverse effects occur no matter its positive potentials towards enhancing sport performances in any way. Athletic trainers and physicians must be aware that herb use is deeply rooted in specific cultures and a key component of folk medicine. Therefore, an appropriate level of cultural sensitivity must be used when discussing the use of these products with athletes. The sports medicine personnel must work in synergy with sports men and provide honest, unbiased information to educate athletes regarding herbal supplements as a potential doping agent. There is the need for athletes to understanding WADA policy of herbal products and those products with potential doping restrictions.

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Authors' contributions

ETF, BM, CNF BH, DJF, BEF draft and revision of manuscript, TN, MDM, NMR, JYN, RN revised manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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