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The Science of Performance: Nutrition and Herbal Products in Sport

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ABSTRACT

There are common goals for nutritional support depending on the type of training and individual factors. The aim is to determine the appropriate type, amount, and timing of nutrient intake and hydration. Additionally, many athletes face the risk of energy deficiency due to an imbalance between energy intake and expenditure. Therefore, before, during, and after exercise, good nutritional strategies, especially carbohydrate intake and fluid replacement, are important. Following the policy of ''food first, but not only food'', dietary supplements can be used to support nutrition and performance. In this context, the use of herbal products by athletes has become increasingly widespread in recent years. However, these products may be used by athletes with the misconception that 'if it is herbal, it is harmless/has no side effects' and as a result, the athlete's performance may be negatively affected. These products, which are used by athletes to support or enhance their physical performance, support the athlete's performance when using the right plant, the standardized product, at the right time, with the right dose. The aim of this review is to identify and explain in detail the practical nutritional recommendations, effects, and herbal products commonly used by athletes in recent years. In conclusion, personalized nutrition and evidence-based supplements contribute to athletic performance and recovery.

1. INTRODUCTION

Sports Performance and Nutrition

Sports nutrition includes sport-related nutrients that enhance physical performance. The metabolic needs of athletes are met by these nutrients and protect physical health and athletic performance. In addition depending on their level of physical activity, age, gender, knowledge, attitudes, and availability of nutritional information sources, athletes have different nutritional needs. The important thing is for individuals, to follow an appropriate nutritional plan because it affects the entire physical process from energy production to recovery after exercise. The main priority of this nutritional plan is to guide athletes to achieve adequate energy intake, provide the body with the right balance of macro- and micronutrients, and then their intake at strategic times to improve athletic performance. Otherwise, training and recovery can be hampered by an inability to achieve adequate energy intake and the right balance of macro- and micronutrients. This can lead to negative effects on performance, reduced lean mass, a weakened immune system, and increased susceptibility to injury. Therefore, maintaining a healthy and balanced diet is very important for an athlete's performance and quality of life [1-8].

The main aim of this review is to present the most recent data on some important medicinal plants included in the publication "Naturally sourced ergogenic supports used by athletes.", published in 2023, and to emphasize nutrition [9].

Energy (Kcal)

Maintaining optimal performance in athletes is based on an adequate and balanced diet and optimal energy intake. The balance in the diet is particularly important for performance and recovery, as well as reducing the risk of illness and injury. In this context, energy availability is the most important concept. Energy availability (EA) represents energy available for physiological functions after subtracting energy expenditure during exercise. In the case of low energy

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availability (LEA), athletes often experience menstrual irregularities, a tendency to eat more, intolerance to illness, reduced mood and efficiency, reduced libido, and hormonal disorders [1]. Athletes should eat 4-6 meals a day (including snacks). Although energy availability and energy balance may seem similar, they are fundamentally different. Energy balance includes all components of energy expenditure, which is particularly important for changes in body weight and composition caused by diet and exercise, whereas EA focuses on energy expenditure during exercise. As a result, a practical option for athletes to maintain energy intake during exercise and support their diet [1, 3, 4, 6].

Macronutrients

Carbohydrate

High levels of carbohydrates in sports nutrition significantly improve athletic endurance and intense exercise performance. This is achieved through the availability of exogenous carbohydrates which are stored as glycogen in the muscles and liver. During exercise, endogenous carbohydrate levels decrease through energy consumption, depending on the intensity and time of the exercise. Rapid ingestion of carbohydrates after exercise quickly replenishes carbohydrate stores and contributes to the development of the body's exercise-induced recovery process. Carbohydrates are the main source of energy for muscle glycogen, blood glucose, and active muscles, so play a role in athletic performance as they can be metabolized aerobically and anaerobically. Providing the body with an optimal carbohydrate intake contributes to post-exercise recovery and the restoration of glycogen stores for subsequent exercise. Recommended carbohydrate levels for athletes vary according to the volume and intensity of training and the inclusion of complex carbohydrates in the diet. For endurance activities and resistance-based exercise at moderate to high intensity, the primary fuel source is largely carbohydrates. Therefore, it is vital to maintain basal glycogen stores of around 80-100g in the liver and 300-400 g in skeletal muscle. Recommended carbohydrate intake for athletes: 5-12 g/kg/day for athletes who train at moderate to high intensity for more than 12 hours per week; 8-10 g/kg/day for athletes who train for longer than this. Avoid foods that empty the stomach quickly, such as refined sugar, starch, and sports nutrition products. Unless there is significant muscle damage, this level of carbohydrate intake has been reported to be effective in maximizing glycogen storage. Exercise type, duration, intensity session, individual differences, and the comfort of the digestive system must be taken into account when determining the exact carbohydrate requirements of athletes. However, there is no denying the fact that athletes seeking maximum physical performance need an optimal carbohydrate intake in their diet [1, 4, 5].

Protein

Maintaining and optimize muscle mass is the main goals of the athlete. For this, protein and amino acids are particularly important in controlling muscle protein synthesis and breakdown. Recent evidence suggests that changes in nutrient intake have a marked effect on muscle protein synthesis. It is therefore very important to consume protein before, during, and after exercise to support muscle repair and remodeling and to enhance post-exercise strength and hypertrophy. Protein intake is linked to a positive effect on muscle protein synthesis (MPS). The anabolic effects of protein sources are influenced by the amounts of amino acids, Branched-Chain Amino Acids (BCAA) concentrations, protein digestibility, rate of digestion, and absorption kinetics. When assessing protein quality, the amino acid composition of proteins is taken into account. Particularly when training with resistance, taking protein with meals 3-4 hours before training will help to maintain muscle growth and improve muscle recovery. Pre-workout amino acid and carbohydrate combinations have been shown to increase muscle size, muscle cross-sectional area, and time to fatigue. Protein has a limited capacity to provide energy to the body, whereas carbohydrates are the primary source of fuel. Therefore, rehydration and simple carbohydrate intake are important during exercise. As well as providing sufficient protein, high-quality protein is also essential. The main food sources of high-quality, low-fat protein are skinless poultry, fish, egg white, very lean beef, and low-fat milk, while protein supplements are usually whey, casein, milk, and egg protein. It is recommended to take a high-quality myofibrillar protein supplement after exercise to increase myofibrillar protein synthesis and rapidly digestible protein such as whey protein at a level of 0.31g/kg. In addition, a 4:1 carbohydrate/protein ratio should be aimed to initiate muscle glycogen synthesis during this period. Intense exercisers have been shown to benefit from a dietary intake of approximately twice the RDA (Recommended Dietary Allowance) (1.4-1.8 g/kg/day) to maintain protein balance. As a result, it is recommended that moderately

trained athletes consume 1.2-2.0 g/kg protein per day (60-300 g per day for an athlete weighing 50-150 kg), while highly trained athletes consume 1.7-2.2 g/kg protein per day (85-330 g/day for an athlete weighing 50-150 kg). Therefore, to help athletes meet their daily protein requirements, additional advice and education may be required [1, 3, 4, 6].

Fat

It is important to increase metabolic capacity, delay the onset of fatigue, help build muscle, and reduce recovery time, consuming adequate amounts of fat is important for athletes. Athletes are recommended to consume between 20% and 35% of total calories from fat and less than 10% from saturated fat. However, high-fat or fat-loading diets are not recommended. Athletes often turn to nutritional supplements to help maintain adequate levels of body fat. Among these, omega-3, a type of Polyunsaturated Fatty Acid (PUFA), is an important one. These include delaying muscle soreness, enhancing anaerobic endurance, improving oxygen efficiency during aerobic exercise, promoting skeletal muscle health, and reducing oxidative stress during exercise. For optimal absorption, it is recommended that omega-3 be taken after or with a high-fat meal. The recommended safe dose of omega-3 is between 450-900 mg/day (max. dose is given as 3 g/day) [1, 3, 4, 6].

Micronutrients

Micro-nutrients are substances, including vitamins and minerals, that are essential for health, development, and reproduction, and that are not synthesizable by the body. Researches show that the intake of micronutrients, as well as macronutrients in athletes, according to the intensity, duration, and form of exercise, has a positive effect on athletic performance. In particular, significant losses through sweat and urine increase the need for micronutrients. In cases where athletes are unable to meet their micronutrient requirements through diet alone, it is beneficial to supplement these nutrients. It has been reported that iron supplementation, especially in cases such as high-altitude training, and vitamin D supplementation in winter sports or indoor activities may be effective in improving athletic performance. In addition, it is known that supplements can contribute to micronutrient deficiencies in low-energy diets, special nutritional conditions such as vegetarianism, illness, and injury [1, 3, 6].

Hydration

To replace fluid loss is very important before, during, and after exercise. It has been reported that a loss of 2% of body fluid can affect performance and cognitive function. Although thirst is considered a good indicator of dehydration, approximately 1.5 liters of fluid is lost from the body before thirst occurs. Athletes tend to lose about 0.3-2.4 liters of sweat per hour during exercise. This loss is not only of fluid but also of a number of minerals (e.g. salt, potassium, calcium, magnesium, and chloride). In short, athletes should include fluid and electrolyte replacement, especially during recovery. Hypohydration can be life-threatening and impair athletic performance, and occurs when an athlete's body fluid levels are lower than normal. In addition, hyponatremia can occur as a result of increased consumption of fluids that are usually low in sodium or sodium-free, such as water, particularly during endurance exercise. Signs and symptoms include; weight gain, edema, nausea and vomiting, low blood glucose, weakness, convulsions, fatigue, headaches, and urinating frequently. To stay hydrated, you should drink approximately 500-600 ml of water or sports drink 2-3 hours before your workout and another 200-300 ml of water or sports drink 10-20 minutes before your workout. During exercise, fluid intake should be compatible with sweat and urine loss. The main aim of post-exercise fluid intake should be to replace fluid lost during exercise or competition. For this purpose, sports drinks are effective in replacing basic electrolytes and lost fluid. This is not recommended for every type of activity but is particularly suitable for strenuous activity lasting over 1 hour, on hot, humid days, when you sweat a lot or when you sweat a lot of salt, or after exercise [1, 3, 6].

Herbal Products

Herbal products contain extracts of roots, stems, leaves, rhizomes, seeds, bark, or flowers, one or more herbal drugs, herbal preparations, or mixtures containing one or more of these herbal preparations. They contain many phytochemicals with potential health effects, including phenolic acids, alkaloids, flavonoids, glycosides, saponins, lignans, etc. Herbal products are regulated as a special category of food by the Food and Drug Administration (FDA) and are classified as "dietary supplements" under the Dietary Supplement Health and Education Act of 1994 (DSHEA). Herbal products are used by both athletes and non-athletes to enhance athletic performance before, during, and after exercise, to increase muscle

tissue and endurance, to delay the onset of fatigue, to minimize damage to the body after exercise, to protect the immune system, to provide vitamins and minerals that cannot be obtained in sufficient amounts through diet, to reduce the body's recovery time after exercise and competition, and to increase the ability to perform motor functions such as conditioning and coordination. However, many of these products have not been fully proven to be safe and effective. Despite the marketing of natural supplements to improve health and physical performance, it has been reported that some plants may contain doping substances. These substances may be included in the Prohibited List, which has been compiled and published annually since 1980 by the International Olympic Committee (IOC), the World Anti-Doping Agency (WADA), and the International Federation (IF). If the substances or metabolites on these lists are found in an athlete's urine or blood as a result of testing, the athlete will be sanctioned [1, 3, 10-14].

Caffeine

Caffeine (1,3,7-trimethylxanthine), is found in the plants *Camellia sinensis* L. (tea), *Coffea arabica* L. (coffee), *Centella asiatica* (L.) Urb. (halik)/ Gotu kola (cola fruit) and *Theobroma cacao* L. (cocoa), is a compound formed by the combination of theophylline, theobromine, and paraxanthine molecules with xanthine. Almost all caffeine taken orally is rapidly absorbed and enters the circulation and reaches high plasma concentrations in about 1 hour. However, this time can be influenced by individual differences (age, sex, body composition, organ function, etc.). In particular, some studies in the literature report that caffeine improves athletic performance regardless of gender, while others report a greater performance advantage in men. The negative health effects of caffeine are minimal and it is therefore accepted as one of the most widely consumed substances in the world. Caffeine is a source often used by athletes as an ergogenic support. Since 2004, when it was removed from WADA's list of banned substances for competition, caffeine consumption has become widespread among inactive individuals and elite athletes, allowing athletes to consume caffeine in any form and in any quantity they choose. There is evidence that caffeine improves athletic performance, but some studies are conflicting due to specific protocols and study designs. Some studies have shown ergogenic effects in aerobic endurance (>90 minutes), high-impact exercise (20 to 60 minutes), muscle endurance, sprint performance and maximal power (0 to 5 minutes), and ultra-endurance events (>240 minutes) involving long interval sprinting (team sport). Caffeine doses of 3-6 mg/kg 60 minutes before exercise are generally accepted for performance enhancement. Taking caffeine early before exercising has been shown to enhance performance. When taken 45-60 minutes before exercise, caffeine improves performance during a high-intensity sprint. Caffeine can and should be taken before or during exercise because it has such a positive effect on exercise performance. For most sports, you should consume caffeine approximately 60 minutes before the first set. The amount of time needed varies, depending on the person, the event, and the type of caffeine used. Some evidence suggests that caffeine is beneficial when taken later in the day and smaller amounts. Anaerobic and aerobic activity can be increased by circadian variations between 4 pm and 8 pm, and caffeine intake is more beneficial at dawn than at dusk. Trained individuals have higher adenosine A2A receptor concentrations. Furthermore, very low dose caffeine (>1-2mg/kg, usually given 60 minutes before exercise) has been shown to improve resistance exercise performance for strength, endurance, and mean speed. In addition, caffeine is readily available in the bloodstream after ingestion. Blood levels peak 15-45 minutes after ingestion. Peak plasma caffeine concentrations usually occur 30-120 minutes after oral dosing. Although the most common source of caffeine consumed by athletes is coffee, it is also known that there are various forms of ergogenic supplements. It has also been shown that caffeine taken in capsule form has a more rapid ergogenic effect than other forms of caffeine. It has been reported that consuming caffeine before exercise increases plasma levels of β-endorphins and reduces fatigue and pain. However, it is known that caffeine's main mechanism of action in the body is through adenosine, an important neurotransmitter. Adenosine binds to adenosine receptors in nerve cells, inhibiting the release of neurotransmitters from the central nervous system, thereby reducing the body's arousal. Because of its similarity to adenosine, caffeine acts like adenosine in the body, delaying fatigue. However, high doses of caffeine can reduce the ergogenic effect during exercise by blocking about 50% of the adenosine receptors to which it binds later in the process. The relationship between caffeine consumption and optimal dose in athletes remains unclear. Most of the available evidence suggests that regular caffeine consumption does not have a negative effect on performance after a single dose of caffeine. Data suggest that doses of 6-9 mg/kg body mass may be necessary to produce a performance-enhancing effect. However, most of

the studies did not report the regular caffeine intake of the participants, more researches are needed to draw more definitive conclusions. It is reported that approximately 3-9 mg/kg caffeine consumption is sufficient for good ergogenic support, while 9 mg/kg or higher doses may cause side effects. It is also emphasized that the caffeine dose may vary depending on the person's frequency of consumption, type of exercise, muscle contraction pattern, and the form of caffeine consumed. Different side effects may be seen if caffeine is consumed in high doses at a time. In this condition, which is called "caffeinism", tachycardia, nausea, vomiting, insomnia, hyperactivity, anxiety, restlessness, and muscle cramps/breakdowns may occur. According to the European Food Safety Authority (EFSA), daily caffeine consumption of up to 400 mg (5-7 mg/kg per day for a 70 kg adult) by adults and 200 mg by pregnant or breastfeeding women is considered safe. It has been reported that approximately 5-10 g/day caffeine consumption in adults may cause caffeinism [15, 16-28].

Rhodiola rosea L.

Rhodiola rosea L. (RR) is a plant widely used in traditional medicine in Europe and Asia. A member of the Crassulaceae family, known as ''rose root'', ''golden root'' or ''arctic root'', this perennial yellow-flowered plant grows naturally in the eastern coastal regions of Europe, Asia (especially Siberia), and North America, in high arctic regions, in dry sandy soils and rock crevices. It has been used to increase physical endurance, work efficiency, longevity, and resistance to altitude sickness, and to relieve fatigue, depression, anemia, impotence, gastrointestinal disorders, infections, and nervous system disorders. It has been used in clinical practice as a traditional treatment with strong antioxidant properties. Phytochemical studies have shown that Rhodiola contains phenylpropanoids, phenyl ethanol/benzyl alcohol derivatives, flavonoids, cyanogenic glycosides, and terpenoids. In addition, its bioactive compounds have been shown to be effective in scavenging reactive oxygen species (ROS). These effects are linked to the fact that natural substances in the root's composition stimulate the production of norepinephrine, serotonin, dopamine, and acetylcholine. These molecules act directly on the cerebral cortex, improving attention, memory, concentration, and mental capacity while increasing resistance to fatigue and physical performance.

Root and rhizome extracts of RR contain the endogenous steroids 4-androstene-3,17-dione, dehydroepiandrosterone (DHEA), and the pseudoendogenous steroid 1,4-androstadiene-3,17-dione. However, there are no reports indicating the formation of anabolic androgenic steroids. Rhodiola has been found to reduce lactate levels and indicators of muscle damage after aerobic exercise in athletes. An intake of 3 mg/kg RR reduced the heart rate response during submaximal exercise and reduced perceived exertion during intense endurance exercise in recreational sportswomen. However, its combination with other plant extracts showed no significant benefit on oxygen consumption, cycling time, or muscle strength. It has also been suggested that RR may prolong muscle recovery time by promoting protein hydrolysis, thereby reducing post-exercise muscle soreness or damage. Elevated levels of CK and CRP in the blood after high-intensity exercise have been associated with muscle damage. RR preparations exhibit adaptogenic properties with neuroprotective, cardioprotective, anti-fatigue, and central nervous system stimulant effects. Mechanisms of action include interaction with the HPA axis (cortisol suppression), protein kinases p-JNK, nitric oxide, and defense proteins. It has been reported that RR generally does not cause serious side effects, its herbal toxicity is low and the doses tested are considered safe for athletes and active individuals. However, further research is needed as there are insufficient mechanisms and evidence to explain its effects on athletic performance. For a variety of reasons, the FDA has included this herb in the Poisonous Plant Database, reporting that there is insufficient evidence to support it as a safe drug or dietary supplement. The place and time of harvest, extraction methods, and the presence or absence of spurious compounds lead to great variability between RR products. In addition, the use of high-performance liquid chromatography is recommended for quality control of RR, as dosage and timing of use can significantly affect results [14, 29-32].

Capsicum annuum L.

Capsicum annuum L. is a plant native to tropical and temperate America, with about 35 species belonging to the family Solanaceae, and distributed from Mexico to Brazil, Paraguay, and central Argentina. *C. annuum* is native to southern Central America and is grown in tropical and sub-tropical countries in Africa and Asia, and in Europe, particularly in Italy, Turkey, and Portugal. C. annuum (red pepper) contains about 300 components, including vitamins C, and E, carotenoids, flavonoids, saponins, capsaicinoids,

polyphenols, and other phytochemicals. The major compound of *C. annuum* is capsaicin. Due to this rich bioactive content, *C. annuum* fruits are an important dietary source. In 1597 it was used to prevent the king from developing severe swelling and was said to have an "obstructive" effect. It was considered a stimulant in the 18th and 19th centuries. Capsicum was mentioned as a powerful local stimulant by the United States Dispensary in 1943. In traditional Indian medicine, it was used as an Ayurvedic herb. Today, *C. annuum* is one of the supplements used by athletes to improve their performance. In particular, capsaicin in its structure has attracted the attention of researchers in sport and exercise science. Classically defined as a stimulant, capsaicin is a known endogenous activator of TRPV1 that modulates heat and/or pain signals in sensory neurons. In addition, TRPV1 is highly expressed in skeletal muscle and its activation can affect muscle contractility. After capsaicin ingestion, TRPV1 activation increases calcium ion release from the sarcoplasmic reticulum, which affects actin-myosin filament interaction, resulting in increased force output. It has also been reported that capsaicin consumption can reduce pain perception and perceived exertion (RPE), factors that may contribute to an improvement in exercise performance. TRPV1 can also stimulate the synthesis of nitric oxide, a potent vasodilating agent, which improves exercise performance by increasing blood flow to the working muscle, the supply of nutrients and oxygen, and the removal of metabolic waste products. Capsaicin stimulates catecholamine secretion from the adrenal medulla, reduces adipogenesis, and increases thermogenesis by increasing energy metabolism. The mechanisms underlying capsaicin's ergogenic effects and fatigue resistance, as well as the effects of supplementation protocols on aerobic endurance, require extensive research [33-40].

Tribulus terrestris L.

Tribulus terrestris L. is an annual plant belonging to the Zygophylaceae family. Although it is native to the Mediterranean region, it grows widely in Turkey, China, Japan, Korea, and some African countries. *T. terrestris* contains important components such as saponins, flavonoids, glycosides, phytosterols, and alkaloids. Throughout history, *T. terrestris* has been used as a folk medicine in China, India, and Greece to improve muscle strength and sexual potency, as well as to treat urinary tract infections, eye problems, edema, gastric swelling, heart problems, and coughs. Today it is known that the root and fruit of the plant in particular have many beneficial effects on the body; diuretic, immunomodulating, antidiabetic, antispasmodic, cardiotonic, anti-inflammatory, hepatoprotective, analgesic, antimicrobial and anticarcinogenic. It has been found that the plant has a high content of saponins, tannins, flavonoids, and resin. The saponins in particular are known to increase testosterone secretion and reduce inflammation and oxidative damage in skeletal muscle, providing an anti-inflammatory and anti-oxidant effect. As a result, studies have shown that it supports muscle performance and increases strength. However, T. *terrestris* should be used with caution, in addition to its beneficial effects on muscular performance, it increases testosterone levels, which can lead to a positive result in doping tests. Therefore, its use in appropriate doses and for appropriate periods is important for the health and performance of the athlete. Although there are no established dosage guidelines, some studies have reported that 3.21 mg/kg of *T. terrestris* per day for 20 days (200-450 mg) may be effective for athletic performance. However, it has been reported that this effect may vary with dose, age, general health, and the product used. Further researches are needed to determine the appropriate dosage [41-45].

2. CONCLUSION

In conclusion; optimal nutrition and the informed use of herbal products are critical components in enhancing athletic performance. While macronutrients and hydration lay the foundation for energy balance and recovery, micronutrients and bioactive compounds derived from plants can offer additional benefits by supporting metabolic pathways, reducing inflammation, and enhancing cognitive focus during physical activity. However, the use of herbal products warrants careful scrutiny due to potential interactions with medications, variability in bioactive compound concentrations, and risks associated with unregulated supplements. The integration of evidence-based nutrition with a precise understanding of phytochemical properties is essential to achieve safe and effective outcomes. A collaborative approach among healthcare professionals, researchers, and practitioners is imperative to minimize risks and ensure athletes are guided by scientifically robust, personalized recommendations.

Conflict of Interest

No conflict of interest is declared by the authors.

Author Contributions

Concept, EB, MSK and GEC; Design, EB, MSK and GEC; Supervision, GEC; Resources, EB and MSK; Materials, EB and MSK; Data Collection and/or Processing, EB, MSK and GEC; Analysis and/or Interpretation, EB and GEC; Literature Search, EB and MSK; Writing, EB, MSK and GEC; Critical Reviews, GEC.

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