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Review Article

The Impact of Nutrition on Oxidative Stress in Athletes: Narrative Review

Atletlerde Beslenmenin Oksidatif Stres Üzerindeki Etkisi

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Abstract: Exercise can have both beneficial and detrimental effects on oxidative stress, depending on factors such as intensity, duration, and individual characteristics. Particularly, high-intensity and prolonged physical activities increase the production of reactive oxygen species, which may overwhelm endogenous antioxidant systems and lead to oxidative damage. Assessment of oxidative stress in athletes commonly involves biomarkers such as lipid peroxidation products, protein and DNA oxidation indicators, and antioxidant enzyme activities. Changes in these parameters during or after exercise provide insight into the level of physiological stress. Nutrition plays a crucial role in the management of exercise-induced oxidative stress. Western-type diets, which are typically low in antioxidants and high in saturated fats and processed foods, tend to worsen oxidative stress. In contrast, dietary patterns rich in fruits, vegetables, whole grains, healthy fats, and phytochemicals—such as the Mediterranean diet— have been shown to exert protective effects. Regular consumption of bioactive compounds like lycopene (tomatoes), polyphenols (grape juice, green tea, pomegranate, aronia, beetroot), tocopherols (nuts and seeds), and flavonoids (sour cherry, cocoa) can enhance antioxidant capacity and reduce exercise-induced oxidative damage. However, it is also emphasized that high-dose antioxidant supplementation may impair physiological adaptations and exert pro- oxidant effects. Therefore, a balanced and antioxidant-rich diet based on natural food sources offers a safe and effective approach for managing oxidative stress in athletes without the need for pharmacological interventions. This review aims to examine the current literature on the effects of nutrition on oxidative stress specifically in athletes.

Keywords: Exercize, elite athletes, nutrition, oxidative stress

Öz: Egzersiz, yoğunluk, süre ve bireysel faktörlere bağlı olarak oksidatif stres üzerinde hem olumlu hem de olumsuz etkilere yol açabilmektedir. Özellikle yüksek yoğunluklu ve uzun süreli fiziksel aktiviteler, serbest radikal üretimini artırarak oksidatif hasara neden olmaktadır. Bu süreçte endojen antioksidan sistemlerin kapasitesi yetersiz kaldığında, kas fonksiyonlarında bozulma ve performans kaybı gözlenebilmektedir. Sporcularda oksidatif stresin değerlendirilmesi, lipid peroksidasyon ürünleri, protein ve DNA oksidasyon belirteçleri ile antioksidan enzim aktiviteleri gibi biyobelirteçler üzerinden gerçekleştirilmektedir. Egzersiz sırasında veya sonrasında bu parametrelerdeki değişimler, fizyolojik stres düzeyinin değerlendirilmesine olanak sağlamaktadır. Beslenmenin oksidatif stres yönetimindeki rolü kritik öneme sahiptir. Düşük antioksidan içeren, yüksek doymuş yağ ve işlenmiş gıda içeriğine sahip Batı tipi diyetler oksidatif stresi artırırken, meyve, sebze, tam tahıl, sağlıklı yağlar ve fitokimyasal içeriği yüksek Akdeniz diyeti gibi modeller oksidatif stresi azaltıcı etki göstermektedir. Bu kapsamda likopen (domates), polifenoller (üzüm suyu, yeşil çay, nar, aronya, pancar), tokoferoller (yağlı tohumlar), flavonoidler (vişne, kakao) gibi biyoaktif bileşenlerin düzenli tüketimi, antioksidan kapasiteyi artırmakta ve egzersiz kaynaklı oksidatif hasarı azaltabilmektedir. Bununla birlikte, yüksek dozda antioksidan takviyelerinin fizyolojik adaptasyonları engelleyerek ters etkiler oluşturabileceği ve pro-oksidatif etkilere yol açabileceği de vurgulanmaktadır. Bu nedenle sporcularda doğal besin kaynaklarına dayalı dengeli ve antioksidan açısından zengin bir beslenme stratejisi, farmakolojik müdahalelere gerek kalmaksızın oksidatif stresin yönetimi için etkili ve güvenli bir yaklaşım sunmaktadır. Derlemenin amacı, sporcularda oksidatif stres üzerine beslenmenin etkilerini güncel literatür doğrultusunda değerlendirmektir.

Anahtar Kelimeler: Egzersiz, elit sporcular, beslenme, oksidatif stres

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INTRODUCTION

Exercise affects oxidative stress either positively or negatively, depending on factors such as intensity, duration, and individual characteristics. The stimulatory effect of exercise plays a role in enhancing the activity of endogenous antioxidants (1). However, prolonged and high- intensity exercise has been shown to induce oxidative stress (2,3). The production of free radicals increases particularly during high-intensity aerobic activities (4). In high-intensity exercise, part of the energy demand is met through anaerobic energy systems. Under conditions of anaerobic energy expenditure, the endogenous antioxidant capacity may be exceeded. This may result in impaired muscle function and elevated levels of lactate and highly reactive oxygen species, both of which contribute to oxidative damage (5). Free radicals are constantly generated in all cells as a natural byproduct of normal cellular metabolism. In defending against oxidative stress caused by free radicals, endogenous antioxidants and dietary antioxidants play a critical role (4).

Studies investigating the effects of antioxidants in athletes have largely focused on nutritional interventions evaluating the impact of antioxidant supplementation (6). One reason for this is the difficulty in quantifying the types and amounts of antioxidants naturally present in foods. However, the beneficial effects provided by antioxidants derived from whole foods are generally not identical to those provided by supplements. Food-derived antioxidants are often accompanied by other bioactive compounds, which may enhance antioxidant activity through synergistic effects. In this context, a diet rich in antioxidants can serve as a natural and effective strategy to maintain the body's antioxidant balance without the need for pharmacological interventions (1). Nevertheless, a common misconception among the general population is that higher intake of bioactive substances, like other beneficial nutrients, results in greater health benefits. Scientific research, however, suggests that high-dose antioxidant supplementation may exert pro-oxidant effects; therefore, athletes are advised to be cautious in their intake of antioxidant-rich foods (2).

Nutritional strategies aimed at mitigating exercise-induced oxidative stress are generally based on two key principles: (i) avoiding dietary components that increase oxidative stress risk, and (ii) incorporating foods with antioxidant properties into the diet (1). This review aims to synthesize current scientific evidence regarding the effects of exercise on oxidative stress and the nutritional management of oxidative stress in athletes. Priority was given to human studies that were directly related to the subject and examined the relationship between nutrition, antioxidant intake and oxidative stress in athletes.

Oxidative Stress Biomarkers

Measuring oxidative stress in living organisms is inherently challenging due to the highly complex network of interactions between oxidants and antioxidants, as well as the extremely short half-life of free radicals. Consequently, instead of direct measurement techniques, indirect biomarkers are commonly employed to assess oxidative stress (7,8). Some of the commonly used biomarkers for evaluating oxidative stress levels are presented in Table (7-9).

Table. Oxidative Stress Biomarkers

Lipid Peroxidation	MDA, lipid hydroperoxides, conjugated dienes, thiobarbituric acid, 4-HNE, F_2-IsoPs or $F_2\alpha$-IP, oxLDL, and TBARS are used as biomarkers of lipid peroxidation.
Protein Modifications	Protein carbonyl content is measured to assess oxidative modifications in proteins.
DNA Modifications	8-OHdG is used as a biomarker of oxidative damage to DNA molecules.
Measurement of Antioxidants	The activity of antioxidant enzymes such as SOD, CAT, and GSH-Px is evaluated. In addition, levels of vitamins A, C, and E, reduced GSH, GSSG, allantoin, and TAS are commonly measured.

MDA: Malondialdehyde, 4-HNE: 4-hydroxynonenal, F_2-IsoPs/$F_2\alpha$-IP: F_2-isoprostanes, oxLDL: oxidized LDL, TBARS: Thiobarbituric acid reactive substances, 8-OHdG: Nucleotide 8-hydroxy-2'-deoxyguanosine, SOD: Superoxide dismutase, CAT: Catalase, GSH-Px: Glutathione peroxidase, GSH: Glutathione, GSSG: Oxidized glutathione, TAS: Total antioxidant status.

Oxidative Stress Status in Athletes

Elite athletes, who are athletes who engage in competitive sports aiming for a high level of physical performance, constitute a primary risk group in terms of oxidative stress. The oxidative stress status among athletes may vary depending on the sports discipline. In a study conducted on elite male athletes from football, basketball, and wrestling, increases in oxidative stress biomarkers were observed in all groups. Among the disciplines, basketball players were found to have statistically higher levels of malondialdehyde (MDA) compared to the other sports branches (10). In a six-month study conducted with a male handball team, regular training programs led to increases in the levels of catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPx), and glutathione reductase. Furthermore, during periods of high-intensity training, a significant rise in MDA levels was reported compared to other training phases (11). Likewise, endurance athletes involved in marathon, half-marathon, ultramarathon, and Ironman events demonstrated increased activities of SOD, GPx, and CAT enzymes (3).

In elite male rowers, oxidative stress was reported to increase in cases of injury and illness (12). Ovchinnikov and Paoli also found a significant increase in lipid peroxidation products in both saliva and plasma samples of female swimmers, indicating elevated oxidative damage (13).

Nutritional Interventions That Increase the Risk of Oxidative Stress

Rapid body weight reduction practices are commonly used among weight-category athletes (e.g., judo, wrestling, karate, taekwondo, boxing). These practices include low-calorie diets, meal skipping, dehydration, and high-intensity training. Such practices may lead to adverse effects on both health and athletic performance and therefore are not recommended by dietitians (14). Rapid weight loss often results in the regain of approximately 104% of the lost body weight within one week (9). In a study involving judo athletes, a seven-day rapid weight loss period prior to competition resulted in increased levels of myoglobin and creatine kinase, which are markers of muscle damage (15).

In another study involving taekwondo athletes, a ketogenic diet combined with calorie restriction for three weeks led to increased levels of high-density lipoprotein (HDL), an antioxidant known to suppress the accumulation of oxidized lipids (16).

Diets lacking in antioxidant-rich foods have been associated with elevated plasma inflammatory markers such as tumor necrosis factor (TNF-α), and decreased plasma antioxidant concentrations, both at rest and post-exercise. A low-antioxidant diet may also influence athletes' perceived exertion during exercise (17). Staśkiewicz et al. reported that both amateur and professional athletes consumed antioxidant-rich fruits and vegetables in amounts below recommended levels (18). In a study that evaluated the effects of switching from a high-antioxidant to a low-antioxidant diet over two weeks, F2-isoprostane levels increased following reduced antioxidant intake (19). Athletes who follow energy-restricted, chronically low-fat diets or limit their intake of fruits, vegetables, and whole grains are considered to be at risk for low antioxidant intake (2).

While increasing antioxidant intake is generally considered beneficial, some studies have reported adverse outcomes from excessive antioxidant consumption. For instance, in a study involving female runners, high doses of vitamin C (≥1 g/day) were found to negatively affect mitochondrial function and reduce beneficial exercise-induced adaptations. Under intense training conditions, high antioxidant intake may even promote pro-oxidant effects (20).

Meat and meat products are fundamental components of the diet in many populations, including athletes. However, excessive intake of meat may exert pro-oxidant effects and increase oxidative stress (21). High meat consumption can elevate reactive oxygen species (ROS) production in the gastrointestinal tract. This is attributed to cytotoxic compounds such as reactive aldehydes, ketones, and epoxides formed through lipid peroxidation. These compounds are generated in the stomach, easily absorbed in the intestine, and subsequently interact with proteins and lipids, leading to the formation of advanced lipid oxidation end products (ALEs) (22).

High-fat, carbohydrate-restricted dietary patterns can increase ketone body production and disrupt gut microbiota balance. Saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) have been shown to reduce microbial diversity. Moreover, excessive intake of simple carbohydrates and imbalanced fructose-glucose ratios may cause gastrointestinal disturbances (23).

A study evaluating the dietary habits of basketball players found that their intake of bread, fruits, vegetables, and fish was below recommended levels. The main sources of fat and protein in their diets were sausage, meat, and eggs. While their overall fat and saturated fat intake was high, omega-3 fatty acid intake was low. This "Western-style" dietary pattern—characterized by high saturated fat and sugar content—has been associated with increased Bacteroidetes and decreased Firmicutes abundance in the gut microbiota, leading to dysbiosis (24).

Due to frequent competitions, athletes often travel extensively. Many athletes report poorer dietary habits during travel, frequently consuming fast food (25). The Western diet, a modern dietary pattern widely debated in nutrition science, is characterized by high intakes of processed and refined foods, red and processed meats, added sugars, and saturated and trans fats, and insufficient intake of fruits, vegetables, whole grains, and nuts. This diet has been strongly linked to various chronic conditions, including obesity, type 2 diabetes, cardiovascular diseases, and certain types of cancer (26).

Nutritional Interventions That Reduce the Risk of Oxidative Stress

Antioxidants can prevent, attenuate, and repair oxidative damage through several mechanisms, including the inhibition of free radical formation, scavenging of existing free radicals, prevention of lipid peroxidation, and protection against DNA damage and protein modification (27). The safest and most effective strategy concerning antioxidants is to follow a dietary pattern rich in antioxidant-containing foods (2, 28). An increase in dietary antioxidant capacity (DaC) has been associated with reductions in F2-isoprostane and GPx levels in elite soccer referees (29).

Schneider et al. evaluated the effects of dietary interventions with normal and high antioxidant levels in triathletes. In a previous study conducted by the same researchers, the high-antioxidant diet included twice the recommended daily allowance (RDA) for α- tocopherol (30 mg), five times the RDA for ascorbic acid (450 mg), and twice the RDA for vitamin A (1800 µg). In both dietary interventions, an increase in superoxide dismutase (SOD) activity was observed. This result is thought to reflect increased micronutrient intake, even under the normal antioxidant diet. However, neither hydrogen peroxide consumption nor glutathione peroxidase (GPx) activity showed significant changes in either intervention (30).

A wide range of plant-based food sources—such as fruits, vegetables, nuts, and seeds—play an essential role in the intake of exogenous antioxidants. Diets rich in plant-based content are thought to exert a positive impact on oxidative stress and offer protection against uncontrolled levels of ROS. In football players, adherence to a plant-based diet has been reported to reduce F_2α-isoprostane (F_2a-IP) levels, although no significant relationship was found with 8-hydroxy-2'-deoxyguanosine (8-OHdG) (31). In a meta-analysis conducted by Dewi et al., fruit consumption was associated with lower malondialdehyde (MDA) levels among athletes engaged in high-intensity training, such as weightlifting, athletics, running, Muay Thai, and combat sports (32).

The Mediterranean diet, characterized by moderate to high intake of fruits and vegetables, olive oil phenolic compounds such as hydroxytyrosol and oleuropein, and a generally high polyphenol content, is considered an effective strategy to help alleviate exercise-induced oxidative stress in athletes (28).

Vitamin C is one of the most widely studied antioxidants in both human and experimental research. It can be consumed in varying doses, either alone or in combination with other antioxidants. However, its protective effects against oxidative stress remain controversial, with inconsistencies largely attributed to dosage differences (20). A daily intake of 200 mg of vitamin C is considered adequate for maintaining plasma and tissue levels, and this amount can be achieved through a diet rich in fruits and vegetables (33).

Lycopene is a compound with antioxidant properties. In a study evaluating the effects of lycopene in tomato juice on oxidative stress, 50 male athletes were randomly assigned into two groups. Individuals in the experimental group consumed 75 mL of tomato juice containing 10 µg of lycopene daily for 60 days after their morning training sessions. The results showed significant increases in glutathione (GSH) and glutathione peroxidase (GSH- Px) levels and significant decreases in thiobarbituric acid reactive substances (TBARS) in the experimental group. Additionally, aerobic performance indicators improved significantly. In the control group, either decreases or no significant changes were observed in these parameters. These findings suggest that lycopene in tomato juice positively affects oxidative stress and has the potential to enhance athletic performance (34).

Nuts such as walnuts, hazelnuts, and almonds are rich sources of polyunsaturated fatty acids (PUFA), including both linoleic acid and α-linolenic acid (ALA), as well as monounsaturated fatty acids (MUFA). Moreover, nuts contain numerous potent antioxidant and anti- inflammatory bioactive compounds including vitamin E (tocopherols), selenium, zinc, magnesium, fiber, phytosterols, and polyphenols (35). Yi et al. reported that consuming 75 g/day of whole almonds (Prunus dulcis) for ten weeks in ten professional male athletes (8 cyclists and 2 triathletes) was associated with improved oxygen utilization (36).

Green tea possesses antioxidant properties primarily due to its catechins, especially epigallocatechin-3-gallate, and polyphenol content. In a study on individuals performing resistance training, the effects of consuming 200 mL of green tea (prepared from 10 mg dried leaves) three times daily for seven days on oxidative stress were evaluated. The study reported decreased luteinizing hormone (LH) levels post-exercise, attenuation of exercise-induced increases in creatine kinase (CK) and xanthine oxidase (XO) activities, and increases in total polyphenols, glutathione (GSH), and ferric reducing antioxidant power (FRAP). However, participants' nutritional status was found to be imbalanced, particularly in vitamin E and carotenoids (37). In exercise-trained rats, catechin supplementation was shown to significantly suppress age-related declines in exercise endurance and reduce mitochondrial dysfunction in skeletal muscle (38).

The effects of consuming 300 mL/day of organic grape juice (Vitis labrusca) for 20 days were evaluated in triathlon athletes. The study reported increased plasma polyphenol, uric acid, and serum insulin levels, alongside decreased glucose and superoxide dismutase (SOD) levels. These effects are thought to be related to the high polyphenol content of grape juice (39). Similarly, de Lima Tavares Toscano et al. reported that consuming 10 mL/kg of Vitis labrusca juice daily for two weeks increased plasma antioxidant activity in athletes. These findings suggest that grape (Vitis labrusca) juice may offer potential benefits for endurance athletes (40). A study with volleyball players evaluating 400 mL/day grape juice consumption for two weeks found reductions in lipid peroxidation and DNA damage post-match (41). Atan et al. assessed the effects of consuming 250 mL/day of hardaliye, a fermented beverage made from grape, sour cherry leaves, and mustard seeds, on oxidative stress in football players. The study reported a significant increase in serum total antioxidant capacity, along with significant reductions in total oxidation status, oxidative stress index, MDA, and nitric oxide levels compared to the placebo group (42).

Aronia melanocarpa contains a wide variety of biologically active compounds including polyphenols such as anthocyanins, flavonoids, and phenolic acids. Petrovic et al. reported a decrease in TBARS levels following four weeks of 100 mL aronia juice consumption in male handball players (43). Pilaczyńska-Szcześniak et al. supplemented the diets of 20 male football players with 200 mL/day of Aronia juice for seven weeks; however, no significant effects on TBARS or 8-OHdG levels were found. The relatively low antioxidant potential of the aronia juice used in the study, compared to aronia extracts and fresh fruit, was suggested as a possible explanation (44).

Sour cherry (Prunus cerasus) contains various phytochemicals including anthocyanins, flavonoids (quercetin, kaempferol, isorhamnetin), flavanols (catechin, epicatechin), gallic acid equivalents, procyanidins, and phenolic acids (45). The antioxidant effects of sour cherry juice in athletes have been proposed to beneficially influence parameters such as muscle damage, muscle soreness, vascular function, and sleep quality (46). Bell et al. investigated the effects of Montmorency tart cherry concentrate (MC) consumption on recovery following intense and intermittent exercise. Consuming 30 mL of MC twice daily for eight days reduced post-exercise muscle soreness and fatigue, improved muscle strength, and enhanced physical performance. These findings suggest that MC supplementation may support recovery following strenuous physical activity (47).

Pomegranate (Punica granatum L.) contains bioactive compounds such as tannins (ellagitannins and gallotannins), ellagic acid and its derivatives, gallic acid, anthocyanins, and proanthocyanidins (48).

High polyphenol levels in pomegranate juice have been reported to reduce free radicals, oxidative stress, lipid peroxidation, systolic blood pressure, carotid artery thickness, LDL oxidation, and increase myocardial blood flow and antioxidant status, thereby lowering cardiovascular disease risk. Additionally, pomegranate has been shown to suppress cellular transcription factors such as Nuclear Factor Kappa B (NF-κB), TNFα, and cyclooxygenase-2(48). Ammar et al. evaluated the effects of consuming 250 mL of pomegranate juice three times daily for 48 hours before training in nine elite weightlifters. Compared to placebo, pomegranate juice intake resulted in a smaller increase in MDA levels (49).

Beetroot is an effective antioxidant source containing abundant natural components such as nitrate, betalains, vitamin C, carotenoids, phenolic acids, and flavonoids (50). In fencers, the effects of long-term beetroot juice supplementation on oxidative stress, inflammation, and muscle damage markers were investigated. After four weeks of beetroot juice supplementation, a significant increase in VO2max was observed. However, this increase was less pronounced in athletes exhibiting high levels of muscle damage and oxidative stress markers (LDH, MDA, β-carotene). An increase in antioxidant enzyme activities (GPx1 and GPx3) was also detected. It was concluded that beetroot juice has potential performance - enhancing effects in athletes (51).

Epicatechin, found in dark chocolate, stimulates the release of vasoactive compounds from endothelial cells, thereby increasing the bioavailability of nitric oxide (NO). In a study by Patel et al. the effects of consuming 40 g/day of dark and white chocolate for two weeks were evaluated in nine male cyclists. The results indicated that the dark chocolate group exhibited reduced oxygen cost during moderate-intensity exercise (52). In a study involving 20 kickboxing athletes, daily consumption of 40 g of dark chocolate containing 80% cocoa limited the increase of oxidative stress via SOD enzyme activity, although no effects on GPx, MDA, and TAC levels were reported (53).

Oats (Avena sativa L.) contain a group of phenolic compounds known as avenanthramides (AVAs), which possess antioxidant properties. A study reported that consuming oatmeal and semi-skimmed (1.5%) milk before exercise reduced exercise-induced ROS production in female athletes. This effect is thought to be related to increased glucose availability in muscles due to the low glycemic index of oatmeal (54).

Dairy products possess antioxidant effects through sulfur-containing amino acids (cysteine), vitamins A and E, carotenoids, enzyme systems (superoxide dismutase, catalase, and glutathione peroxidase), and equol, a polyphenolic metabolite of daidzein (55). Milk is a recovery beverage that benefits muscle performance by increasing antioxidant levels via whey and casein proteins and provides rehydration post-exercise through its electrolyte content (56). Lactose in milk positively influences gut microbiota by increasing Bifidobacterium and Lactobacillus populations. Polyunsaturated fatty acids (PUFAs) reduce the Firmicutes/Bacteroidetes ratio and increase butyrate-producing microorganisms with anti- inflammatory effects. Omega-3 PUFAs, in particular, are proposed to beneficially modulate gut microbiota and possess prebiotic properties (23). After high-intensity exercise, consuming 500 mL of cow's milk was found to increase total antioxidant capacity (TAC) levels (57). Mazani et al. evaluated the effects of consuming 450 mL/day probiotic yogurt containing Lactobacillus spp. for two weeks on exercise-induced oxidative stress. The intervention resulted in increased GPx and TAC levels and decreased TNF-α and MDA levels (58).

Date fruit (Phoenix dactylifera L.) contains common phenolic acids such as caffeic, gallic, ferulic, and p-coumaric acids. Carotenoids include lutein, zeaxanthin, and β-carotene. Dates are used in many functional foods formulated for athletes, including energy bars, gels, and drinks. They reduce exercise-induced inflammation and oxidative stress, thereby contributing to faster recovery and decreased risk of damage (59).

Koivisto et al. evaluated the effects of a diet rich in antioxidants during a three-week altitude training camp in 31 elite endurance athletes. The antioxidant-rich dietary model included 750 mL of fruit, vegetable, and berry smoothie, 50 g of dried fruit and strawberries, 40 g of walnuts, and 40 g of dark chocolate (70% cocoa content). The study reported increased ferric reducing antioxidant power (FRAP) levels and decreased micro-CRP levels, with no significant changes in TNF-α and 8-epi-PGF2α levels (60).

CONCLUSION

This review has evaluated the biomarkers of oxidative stress associated with high-intensity exercise in athletes and the nutritional strategies that influence this stress. The literature indicates that regular exercise stimulates endogenous antioxidant systems, resulting in beneficial adaptations. However, prolonged, high-intensity exercise unsupported by adequate nutrition may increase oxidative stress in athletes engaged in competitive sports. The effects of antioxidant supplementation vary depending on dosage, duration, and individual needs. Nevertheless, performance should not be the sole criterion for antioxidant use in athletes.

Athletes who adopt a balanced diet rich in natural antioxidants are more effective both in reducing oxidative stress and maintaining performance. In this context, the Mediterranean dietary pattern, characterized by abundant consumption of fruits, vegetables, nuts, whole grains, olive oil, and foods high in polyphenols, may play a protective role against oxidative damage in athletes. Future controlled studies across different sports disciplines will help clarify the relationship between nutrition and oxidative stress, thereby contributing to the development of sport-specific dietary recommendations.

Declarations

Narrative review article based entirely on previously published data and do not involve any human or animal subjects, experiments, or patient-identifiable information. Therefore, ethical approval was not required for this type of article.

Authors' Contributions
Conceptualism and Language editing: AÖ, Literature review, writing and discussion: GA, RNS
All authors have read and approved the final version of the manuscript. Each author meets the ICMJE authorship criteria and accepts responsibility for the integrity and accuracy of the work.
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