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An overview of nutritional strategies for recovery process in sports-related muscle injuries

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Abstract

Introduction: Muscle injuries are common among elite athletes and compromise competitions and training schedules. Within the interventions to treat a sports injury, the nutritional approach is key to improve the physiological response and maintain the body composition to promote a quick and safe return to the play.

Objective: Present an overview of the nutritional strategies and recommendations after a muscular sports injury, emphasizing the use of main nutrients and elements for the muscle recovery, such as proteins, antioxidants, omega 3 fatty acids, and probiotics.

Methodology: The search of information was made in the PubMed, Science Direct, Scielo, Embase, and Google Scholar databases under specific DeCS and MeSh terms. The selected articles included literature reviews and clinical trials related to muscle injury in high-performance athletes, in any sports discipline or in immobilized patient (healthy men or women).

Results: The stages of a muscle injury are classified as destruction-inflammation, repair, and remodeling phase. In all stages, energy recommendations should follow the estimated energy requirement plus the injury/stress percentage of increase (10–15%). During the repair phase, the optimal protein consumption (1.6–2.5 g/kg/day divided in several meals with 20–35 g of protein per meal) is crucial for muscle mass maintenance and to reduce the anabolic resistance of skeletal muscle in case of injury. Antioxidants intake from food sources may control the oxidative stress, which occurs during the inflammatory phase, as well as omega 3 fatty acids through stimulation of anti-inflammatory pathway. Moreover, probiotic consumption has been investigated in sports field with the goal of improving muscle repair by enhancing protein absorption capacity and immune cells function at the intestine.

Conclusion: According to the literature, it is necessary to carry out clinical studies with injured athletes and determine how the consumption of nutrients and elements such as probiotics can influence the recovery processes of injured athletes. Also, there are little research in this area of sports nutrition.

Keywords: Injury, Muscle, Sports, Energy intake, Proteins, Antioxidants, Probiotics

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Background

The prevalence of sports injuries is latent in any sport event, from amateur to large events such as World Championships and Olympic Games (summer and winter seasons). The most recent data of injuries or illnesses in big sports event were recorded in the last two Olympic Games: London 2012 and Rio 2016. For instance, in Rio 2016 there was an incidence of 128.8 injuries and 71.7 diseases per 1000 athletes. According to these data, sports like taekwondo, judo, football, and athletics were classified as at high risk of injury, they presented the majority of the register of muscular tensions, followed by fractures and lateral knee injuries [1]. Additionally, data from medical staff showed a major incidence in bike motocross (BMX) (38% of the athletes injured), boxing (30%), mountain bike cycling (24%), taekwondo (24%), water polo (19%), and rugby (19%) [2]. In the Paralympic sports in London 2012, the incidence rate of injuries was 12.7 per 1000 athletes—days; the most common types of injuries during these events were strain muscle and rupture/tear ($n = 168$) [2].

Muscle injury is defined as a traumatic distraction or overuse injury of a muscle [3]. The muscle injuries constituted 31% of all injuries and the 27% of the reasons for absence in professional footballers [3, 4]. This kind of damage is classified in indirect muscle disorder/injury or direct muscle injury. The first one is divided in functional muscle disorder and structural muscle injury [5, 6]. The functional muscle disorder refers to the painful muscle injury without evidence of muscle fiber damage, and the structural muscle injury consists of any acute indirect muscle disorder with macroscopic evidence of muscle fiber damage [5–8].

Based on the previous numbers of muscle injuries and time spent to the athletes' recovery, the use of sports-related recovery strategies is essential to enhance the recovery process and athletes' health. The physical therapy is the first line of therapy in all kinds of injury. For example, the RICE method (rest, ice, compression, and elevation) and the therapeutic ultrasound, followed by the medication treatment with nonsteroidal anti-inflammatory drugs (NSAIDs) and glucocorticoids [7]. During the recovery process, including the first stages of therapy, the nutritional intervention is fundamental to ensure the highest energy and nutrient requirements needed for the repair, wound healing, and control of inflammation and oxidative stress caused by the injury. For the mentioned reasons above, elements such as high-quality protein, antioxidants, omega 3 fatty acids, and probiotics may have an important role in all the recovery process. The dietary protein is used for repair of damaged tissues and prevention of muscle catabolism [9], the antioxidants and anti-inflammatory compounds mediated the gene expression of inflammatory cytokines after the injury [10], and the probiotics improve the immune system response in the muscle repair [11–13].

The aim of the review is to present an overview of the nutritional strategies and recommendations after a muscular sports injury, emphasizing the use of main nutrients and elements for the muscle recovery, such as proteins, antioxidants, omega 3 fatty acids, and probiotics.

Methods

A search of the information was made in the PubMed, Science Direct, Scielo, Embase, and Google Scholar databases under the following DeCS and MeSh terms with the selected articles for each one: "Nutrition AND Muscle Injury" ($n = 8$), "Protein intake AND muscle injuries AND athletes" ($n = 6$), "Protein intake AND immobilization" ($n = 3$), "Whey protein AND muscle injury AND athletes" ($n = 2$) "Omega 3 AND muscle injury" ($n = 6$), "Oxidative stress AND injury AND antioxidants" ($n = 18$), "Bioactive compounds AND injury AND muscle" ($n = 9$), "Probiotics AND Injuries" ($n = 5$). The article selection process was given by the title analysis, which should contain the two MeSH search terms, then the selection of articles by abstract reading and complete reading of relevant papers according to the following eligibility criteria.

The selection criteria for articles were (1) literary reviews and clinical trials, (2) reviews and original research made in the last 25 years (1992–2017), (3) written in English, Spanish, or Portuguese, and (4) including muscle injury or related to high performance athletes, any sports discipline, or immobilized patient (healthy men or women) after an ambulatory, immobilization process, or bed rest in injury situation.

Figure 1 shows the search methodology and selection of articles for each DeCS and MeSh term with the total number of articles analyzed for this review.

Results

Physiology and healing process of muscular sports injury

A sport injury requires a particular nutritional intake, according to the degree of immobilization, the decrease in physical activity, and the degree of muscle mass loss, its strength and function [14]. In this sense, it is crucial to keep in mind the recovery stages of the muscle injury and how the nutritional process can determine the times of regeneration and return to the sports activity. These stages are classified as destruction-inflammation, repair, and remodeling phase [4, 7, 8, 15]. At first, there is an inflammatory response through the first 4 to 6 days, which is modulated by inflammatory mediators like cytokines and growth factors transforming growth factor (TGF), platelet-derived growth factor (PDGF), vascular endothelial growth factor (VEGF), epidermal growth factor, and fibroblast growth factor (FGF) that allows a

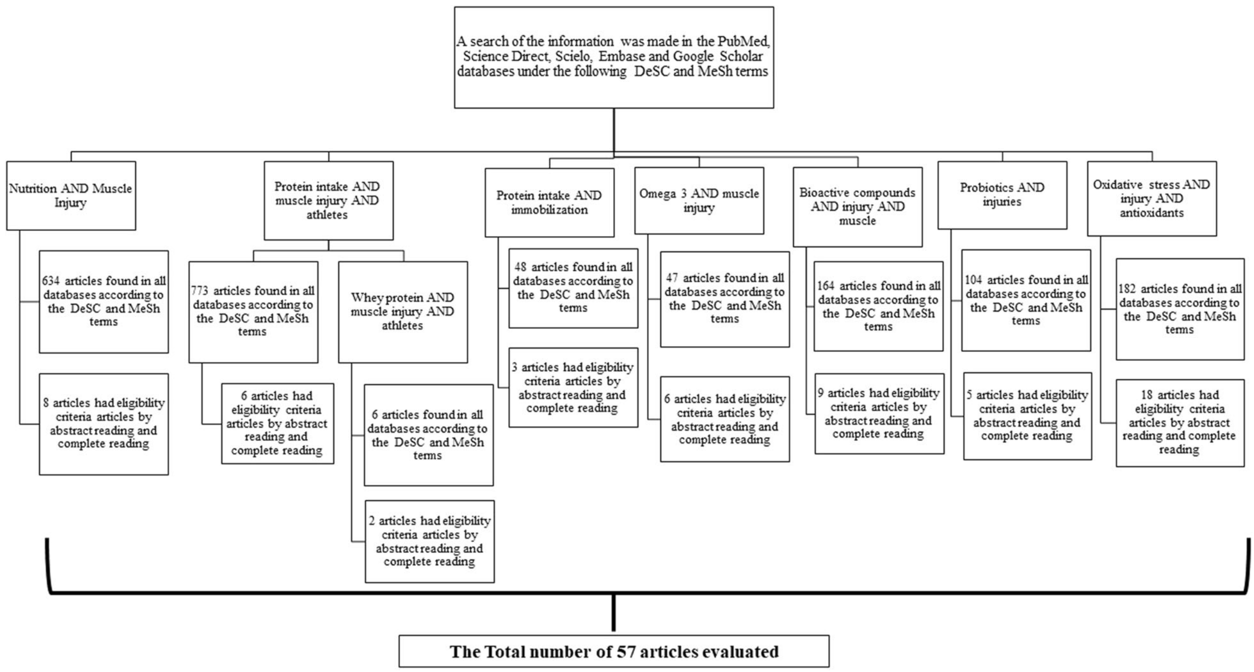

Fig. 1 Methodology of the selection and inclusion of articles

vasodilatation and the migration of immune system cells (e.g., neutrophils, monocytes, and macrophages) into the extracellular matrix (ECM) [8]. This inflammation continues several days, depending on the severity, and it is an important step for the healing process [16]. In this initial phase of the muscle injury, there is a reduction of the physical activity or complete immobilization, which is mandatory and beneficial for two purposes, the speed of the recovery as well as it fosters a most complete recovery; after this process it is recommended the active rehabilitation [7].

The proliferation phase starts around the fourth day and 2 weeks after the injury and it consists in the formation of new capillaries through the production of nitric oxide (NO) via endothelial NO synthase in response to hypoxia, causing vasodilation and increased blood flow to the site of injury [8], in the case of the muscle occurs with proliferation and differentiation of satellite cells and generation of new myofibers to replace those that were injured [15].

The remodeling or maturation phase usually begins 1 week after the injury and can continue for 1 year or more. In that case, fibronectin is the initial component in the extracellular matrix that forms a preliminary fibrous scar during this phase of wound healing. This formed scar has two key functions: as a template for collagen deposition and as a platform for cell migration and cell growth [17]. In the muscle, the maturation of the regenerating myofibers includes formation of a mature contractile apparatus and attachment of the ends of the regenerated myofibers to the intervening scar by newly formed myotendinous junction [7].

Nutrition's role and energy balance in sports injuries

According to all physiological stages of the recovery process, the proliferative stage is important in the increase of collagen matrix and fibroblast synthesis; moreover, in the remodeling stage the increase in the production of collagen type II [14], both could determine the energy consumption that must be considered to avoid caloric restrictions which are frequent in this type of situation.

The energy expenditure depends on the degree of inflammatory response, more than the extent of tissue injury, which is the determinant of hypermetabolism [17]. It has been documented that there is an increase of 15 to 50% of energy expenditure [16]. In a study made in nine healthy volunteers, it was assessed the changes in the lean body mass (LBM) and the Leucine rate of appearance (protein synthesis) in 14 days under different physical activity levels, ambulatory and bed rest conditions, subjects received an eucaloric diet and a hypocaloric diet [18]. In the results, it was found than resting energy expenditure (REE) relative to LBM did not differ significantly between the ambulatory and bed rest conditions during the eucaloric and hypocaloric diet [18]. Hypocaloric nutrition led to the greatest wasting of LBM in bed rest conditions; however, in the ambulatory group the same nutrition allowed a significantly higher leucine deposition rates within the total body protein (protein synthesis). The negative energy balance conditions can lead to a rapid loss of LBM and that such catabolic effects can be prevented, at least in the short term, through a moderate level of physical activity [18].

Another research from Biolo G et al. in 2008 made in 19 healthy men, different physical inactivity conditions and energy intake were evaluated: at first ambulatory adaptation condition (all subjects with the same energy intake) and after 5 weeks of bed rest, under high energy balance (HEB) and lower energy balance (LEB). As a result of this, the HEB and muscle atrophy were associated with the activation of systemic inflammatory response and antioxidant defenses in stress conditions; for example, in the increase of glutathione synthesis, myeloperoxidase concentrations, significant changes glutamate-cysteine ligase enzyme and the rate of glutathione turnover [19]. In relation to body composition, most of the subjects who gained more body fat mass (especially in the HEB group) suffered the greatest loss of skeletal muscle and body free mass.

Although the energy expenditure in muscle injury can be variable, it is important not to make any significant caloric restriction, so reducing physical activity is more important to preserve muscle mass and energy intake, which is increased by physiological responses such as increased inflammation, repair of injured tissue, and remodeling/healing. Exceeding caloric intake above the calorie recommendations that athletes normally consume may have negative effects on body composition (increase in fat mass due to reduced physical activity) without any benefit in physiological responses to a sports injury.

According to this, an increase of 10 to 15% of the estimated energy requirement (EER), from 200 to 500 Kcal maximum could contribute to maintaining energy expenditure increased by the injury process and maintain muscle mass, without generating excess energy that can change the body composition (Fig. 2).

The importance of protein consumption in the processes of muscular sports injury

The periods of immobilization following a muscle injury, especially at week one and two, the rate of muscle protein synthesis decreases if the 10 days of disuse are exceeded with a small or no contribution in muscle catabolism [20]. However, some research also suggests that reduced mobility decreases the sensitivity of skeletal muscle to anabolic properties of amino acids [20]. Within the anabolic resistance, there is a cascade of metabolic reactions, including an interaction between the reactive oxygen species produced by the immobilization and the signaling pathways of IGF-1, the latter pathway is inhibited by the high reactive oxygen species (ROS) production to insulin resistance [21].

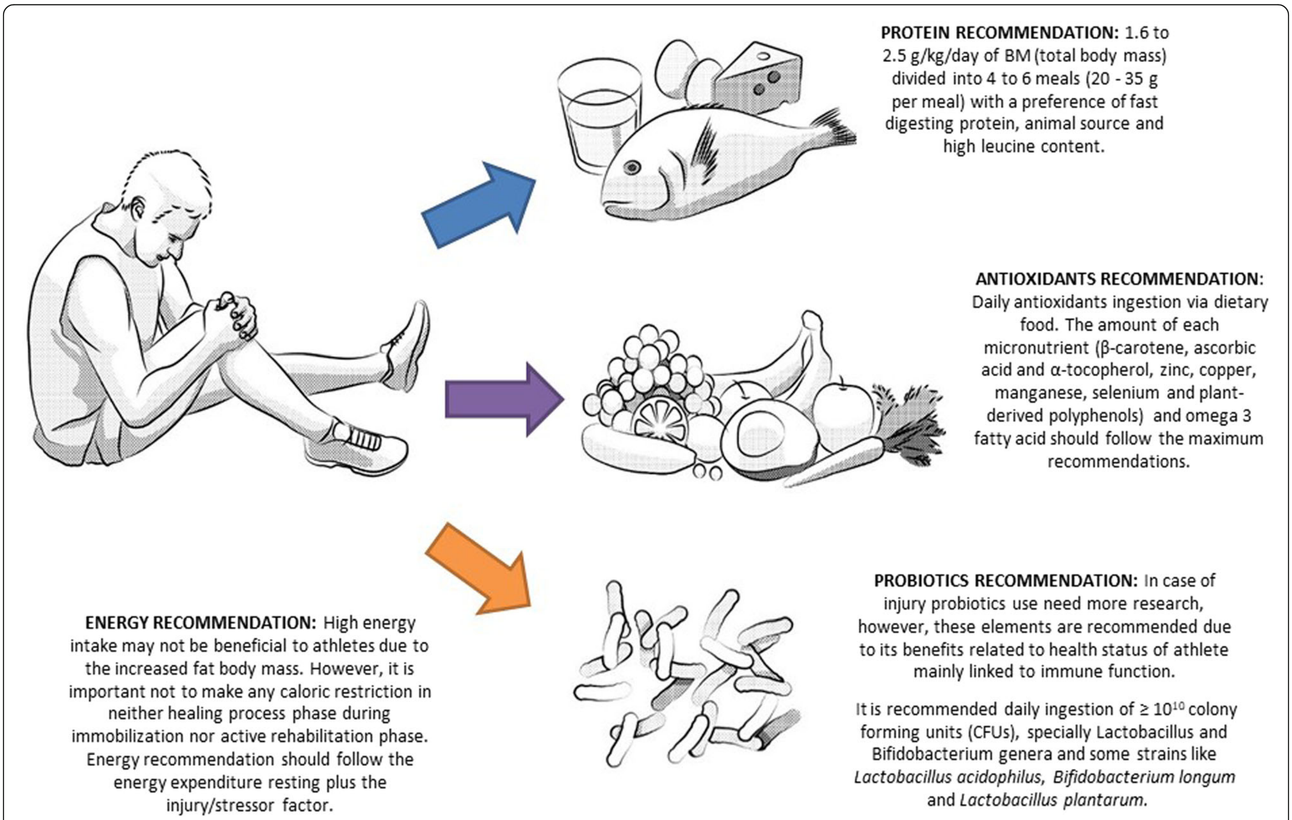

Fig. 2 Main nutritional recommendations related to energy consumption, protein, antioxidants, and probiotics in sports muscle injuries

A positive balance in protein consumption is necessary for the repair of muscle damage produced by exercise [22]. The same happens when there is an injury that implies a reduction of physical activity of the athlete, but in this opportunity the protein consumption must be according to the reduction of the fasting synthesis rate [9] and the reduction of muscle protein synthesis in response to protein intake [20], due to the reduction of the ability of myofibrillar proteins to respond to amino acids in immobilization [23].

In that sense, in 12 healthy young men in 14 days of knee immobilization were measured the protein synthesis after protein intake before and after a period of disuse the immobilization period led a significant decrease to an 8.4% ± 2.8% and 22.9% ± 2.6% in quadriceps muscle cross-sectional area and strength. Related to the energy and protein intake between the volunteers before and after the immobilization, the energy intake average was less after immobilization, also was demonstrated that 14 days of immobilization induced an 30% reduction in the muscle protein synthetic response to the ingestion of 20 g dietary casein protein [20], also no significant increases in phosphorylation of mTOR and p70S6K (mTOR's substrate that regulates mRNA translation) were reported after immobilization time. Beyond these results, in the context of sports performance, it should be kept in mind that the level of physical activity is important to maintain a normal response in postprandial protein synthesis at muscle level and that it will also change according to age [24], in the case of high-performance athletes, although there is no evidence of anabolic resistance in lesions, it is clear that the adaptations induced by physical activity play a major role in delaying or reducing the effects of anabolic resistance to the consumption of protein.

Due to the above several studies document the different degrees of muscular atrophy by disuse depending many times on the duration of the injury or the immobilization phase, it has been shown that in 1 week of immobilization in 10 healthy young males in energy balance, there is a reduction of muscle mass in 3.2 ± 0.9% in quadriceps cross-sectional area (CSA) and 1.4 ± 0.2 kg of lean tissue loss; moreover, bed rest can lower insulin sensitivity by as much as 30%. A significant increase in angiogenic markets like HIF-1α protein expression was observed following bed rest but without changes in skeletal muscle capillary density, measured by immunohistochemistry [25].

Based on the concepts above, nutritional strategies that could be used during immobilization and recovery to overcome this anabolic resistance, should be given from two main approaches: the first is to provide more anabolic factors and improve amino acid availability, i.e., nutrients that can achieve stimulation of the synthesis of proteins and the second is to decrease the threshold of anabolic resistance, i.e., restore the muscle sensitivity to the stimulant effect of food intake, especially in the postprandial phase [26, 27].

Regarding the recommendation of protein consumption during the period of muscle disuse, it should be taken into consideration that in healthy adults the muscle tissue responds to a dose of protein of 20 to 25 g, which maximizes the response of muscle protein synthesis (MPS) in both fasting and exercised muscle [16].

When there is a sports injury situation with immobilization or reduced physical activity, it is likely that the amount of protein in each dose needed to stimulate MPS increases. About this, the currently International Society of Sport Nutrition (ISSN) position stand establish, according to reviews about protein intake and timing in exercise that an ingestion of a protein dose of 20–40 g (0.25–0.40 g/kg body mass/dose), including in all meals a high-quality source every 3 to 4 h during the day, it performs a favorable role in the MSP rates when it is compared with other dietary strategies [28]. Furthermore, they summarized that the ingestion of 10 g/day of essential amino acids (EAA) in free form or as part of the meal timing above, this for maximized the stimuli of muscle protein synthesis (MPS), as well is important that adding sources of leucine to a moderate amount of protein consumed during regular meals (25 g of protein/meal) would serve as an anabolic activator [29], it could work during a process of immobilization or reduction of physical activity in the injured athlete.

In a research made in 19 middle age healthy adults to response to leucine (LEU) and placebo supplementation (CON), all subjects passed over two process, at first an ambulatory phase (1–4 days both groups with the same diet and without supplementation) and then the bed rest (14 days). The results of this research demonstrated that the bed rest reduced the post absorptive MPS in CON group by 30% (± 9%) and 10% (± 10%) in LEU group, that group boosted the muscular endurance by the maintaining of the VO2 peak in bed rest and reducing the accumulation of body fat mass. Although these are short-term effects, because the leucine effects on lean mass are only during the first 7 days of the 14 days protocol, in the final 7 days the rate of loss of lean mass in the LEU group was similar to that in the CON group [29].

In a study conducted with elderly patients hospitalized for hip fracture, the intervention group ($n = 20$) received 32.2 g of whey protein in the pre- and post-rehabilitation period in a postoperative period for 2 weeks. Participants in the whey protein group had significantly greater improvements in knee extension strength in the operated limb and non-operated limb compared with the control group and improvement in functional activities of daily life [30].

Whey protein supplementation can be essential for the maintenance of muscle strength during a period of postoperative immobilization along with an active rehabilitation process, it can also mitigate the increase of physiological markers of muscle damage such as creatine kinase (CK) and lactate dehydrogenase (LDH) [31], and contribute to the recovery of the skeletal muscle after exercise and injury. A recommended intake of whey protein between 20 and 40 g/meal can help reduce muscle loss and improve muscle protein synthesis [30]. The consumption of sources of essential amino acids, especially the sources of leucine (whey protein, casein, and BCAA's), promotes the synthesis of muscle mass and the delivery of amino acids to muscle tissue [26], especially in case of catabolic muscle injury.

According to the intake recommendations in injured athletes, it should mitigate muscle loss during a period of negative protein balance [16], so the recommendation should be 1.6 g/kg/day [32] to 2.5 g/kg/day of total body mass (BM), which is the recommended intake for athletes, this for maintenance of muscle mass. The recommendations of protein intake from the International Society of Sport Nutrition (ISSN) position stand, 1.4–2.0 g of protein/kg body weight/day (g/kg/day), are appropriate for the maintaining of muscle mass, allowing the protein synthesis through a positive muscle protein balance [33], in this point is relevant to clarify that the ISSN position stand is for healthy and exercised individuals, so it is not specifically for injured athletes.

In agreement with the last Position in Nutrition and Athletic Performance from Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine, in cases of energy restriction or reduction of physical activity as it happens as a result of an injury, the increased protein intake of up to 2.0 g/kg/day or more, fractionated throughout the day, can be beneficial to prevent the loss of fat-free mass [34]. This recommendation could be used in the nutritional approach of the injured athlete without the need to provide less or more protein than this recovery process implies, still there is no evidence or clinical trial related to athletes (male or female) in any sports disciplines or according the type of injury and the physiological specificities of the recovery process.

Antioxidant and anti-inflammatory nutrients intake during recovery from sport-related injury

Sport-related damages and injuries favor free radicals and ROS production and other inflammatory molecules [35]. Under normal physiological conditions, the endogenous antioxidant defense can remove or neutralize these detrimental molecules. Oxidative stress, produced when there is an imbalance between free radicals and the endogenous antioxidant defense, can cause lipid peroxidation, DNA damage, and activation of stress-sensitive signaling pathways, which contribute to inflammation maintenance, symptoms of injury (e.g., loss of muscle strengthen, muscle soreness, leakage of cellular proteins into the blood), and it may prevent recovery from injury and wound healing [36, 37]. In the case of athletes who were immobilized or with reduced physical activity of a specific limb due to sport-related injuries, oxidative stress contributes to muscle atrophy by increasing the expression of components of the proteasome proteolytic system. For instance, ROS can activate a group of proteases, known as caspases, that degrade proteins and it may trigger apoptosis [38, 39]. In order to attenuate oxidative stress and their consequences abovementioned, the intake of antioxidant nutrients has been considered as a concern by athletes [16].

Some micronutrients, such as vitamins A (β-carotene), C (ascorbic acid), and E (α-tocopherol), trace minerals as zinc, copper, manganese, selenium, and plant-derived polyphenols are known as antioxidant nutrients that play an important role on redox balance along with the endogenous antioxidant defense [37]. They act by preventing ROS and free radicals formation, and behave as scavengers or proton donors in order to regenerate or repair oxidative damages (Powers et al. 2004) [40]. Besides that, vitamin C is important for recycling the α-tocopherol from oxidative reactions. Vitamin E, as well as polyphenols and β-carotene, has an important role in the conversion of ROS and free radicals to less reactive forms, at cellular membrane, contributing to restrain lipid peroxidation. In addition, the minerals act as co-factors of the superoxide dismutase (SOD) and glutathione peroxidase (GPX), two important enzymes from the endogenous antioxidant defense [37].

Studies that demonstrated positive outcomes after antioxidants supplementation were mostly performed in sedentary, physically active individuals or elderly people after acute exercise [41–44]. However, at the athletes' perspective, there are controversial outcomes in the context of sports performance or sport-related injuries, mainly because of antioxidant type, dose of supplementation, and the nutritional status. Indeed, a growing body of evidences indicates that free radicals and ROS production are necessary to an adequate post-exercise response, according to "hormesis theory" [45]. Thus, if athletes do not present nutritional deficiencies, antioxidant supplementation may favor oxidative reactions and blunt important pathways for positive exercise adaptations, recovery, and wound healing [45–47]. For instance, a mixture of antioxidants supplementation (400 mg of vitamin C, 272 mg of α-tocopherol, 30 mg of β-carotene, 2 mg of lutein, 400 mμg of selenium, 30 mg of zinc, and 600 mg of magnesium) did not offer protection against exercise-induced lipid peroxidation and inflammation, which may hinder muscle recovery in athletes [48].

Likewise, vitamin A daily supplementation (450 retinol equivalents/day) during 8 weeks of swimming training caused lipid peroxidation, protein damaged, and downregulation of SOD-1. Also, vitamin A supplementation decreased anti-inflammatory interleukin (IL)-10 and heat shock protein 70 expression [49]. Other studies have shown that vitamin C (≥ 1 g/day) alone or in combination with vitamin E (≥ 300 IU) did not significantly reduce oxidative biomarkers in athletes and have no effect on recovery after exercise-induced damaged [50, 51].

As a matter of fact, doses higher than 250 mg/day of vitamin C may show prooxidant effects and may reduce mitochondrial biogenesis even in athletes under high-intensity training [45, 52]. A meta-analysis did not find a significant protection against either exercise-induced lipid peroxidation or muscle damage after vitamin E supplementation [53]. Likewise, polyphenol-rich plant supplements have small effects in increasing antioxidant capacity, but countermeasure effects on exercise-induced oxidative stress and inflammation [54]. For example, higher doses of quercetin (1 g/day), a polyphenol-type, for 3 weeks, did not change levels of inflammatory and oxidative biomarkers in ultramarathon athletes after a competition [54]. A majority of studies have supported that antioxidant supplementation does not enhance antioxidant capacity in non-nutritional deficient athletes [45, 55–59]; however, a critical approach is necessary for athletes who have undergone sport-related injuries.

On the other hand, athletes that have received nutritional intervention via food intake have shown higher levels of total antioxidant capacity and endogenous antioxidant activity (SOD and GPX) compared to the ones who do not follow this intervention [60]. Organic grape juice intake (300 ml/day), which is a source of polyphenols, for example, improved antioxidant capacity and also glucose homeostasis in male triathletes [61]. Also, the Mediterranean diet, characterized by high consumption of monounsaturated fatty acids from olives, fruits, vegetables, and whole grains, low consumption of red meat and moderate use of red wine can enhance antioxidant defenses and improves the lipid oxidation [62, 63]. Pingitore et al. (2015) support that, faced with the controversial results about supplementation, feeding seems to be a good non-pharmacological choice in order to provide an antioxidant effect and maintain a recovery process.

Omega 3 fatty acid (n-3FA) has also been considered in the context of nutritional support for sport-related injuries due to its anti-inflammatory and immunomodulatory properties [10]. For instance, omega 3 fatty acid supplementation has also shown capable of attenuate oxidative biomarkers in athletes who had undergone knee surgery [64]. Fish oil intake could play a role in the amelioration of muscle loss with disuse favoring protein synthesis response in both young and older adults [65, 66]. Nevertheless, other studies have found high fish oil consumption may play an inhibitory role on muscle mass recovery [67] and wound healing [8]. Cold-water dwelling fish (e.g., mackerel, sardine, salmon), fish oil, chia, linseed, and walnuts are good sources of n-3FA, and authors have suggested a daily consumption of these food sources to achieve its beneficial effects [68]. In addition, some micronutrients are important in various aspects of wound healing, including muscle disuse. For example, calcium and vitamin D are essential for bone shaping whereas vitamin C is necessary for collagen formation [16]. Vitamin A contributes to collagen synthesis and may revert the corticosteroids-induced inhibition in wound healing [8]. Furthermore, ubiquinone, also known as coenzyme Q10 (CoQ10), plays an important role as an essential electron carrier in the mitochondrial respiratory chain. It seems that CoQ10 supplementation (3 to 5 mg/day) may reduce oxidative stress in athletes [69]; however, there are no sufficient studies for a better conclusion.

As mentioned previously, careful consideration of the use of antioxidants and anti-inflammatory nutrients supplementation is necessary given the importance of the ROS-mediated physiological signaling and inflammatory response for positive adaptations and wound healing [70]. Studies have demonstrated that athletes, without micronutrients deficiency, present a higher total antioxidant capacity, increased antioxidant enzymes activity (SOD and GPX), and higher plasma levels of ascorbic acid (vitamin C) and α-tocopherol (vitamin E) compared to sedentary individuals [71, 72]. Indeed, antioxidant nutrients are important for antioxidant defense system, exercise recovery, and sports performance; however, the appropriate dose of nutrients consumption for injured athletes has not been established, and the individual nutritional status and oxidative biomarker levels have to be considered before supplementation recommendation [73, 74]. For this, researchers have suggested that food intake within the Recommended Dietary Allowance (RDA) recommendations [75] seems to be a safer source of antioxidants and n-3FA (balanced and varied meals as well as fruit and vegetables), and it can guarantee an optimal antioxidant status. Moreover, natural foods can also confer multiple biological effects due to its nutritional composition [45–47].

Probiotics in muscle repair

Probiotics are defined as live microorganisms that confer a health benefit on the host when administered in adequate amounts [76], currently in the sports science, the probiotics elements are recommended accounting their benefits related to health status of athlete [77, 78]. The supplementation with probiotics has been investigated in several endurance sports, like running, cycling, and swimming, in individual sports (tennis, karate or alpinism), and in team games (rugby and football) [79].

Though the number of studies in thematic be limited, and the evidence mass be related to use of probiotics linked to upper respiratory infection and symptoms [80], recently some articles target the possible link between probiotics use muscle damage and repair [11–13]. Although some authors propose a fast effect in muscle repair from probiotic use, these evidence refers to resistance training and in addition to other nutritional supplements that have direct influence in the protein synthesis (e.g., whey protein, β-Hydroxy β-methylbutyric acid-HMB) [11, 13], the probiotic role is difficult to understand.

It is known that probiotics are capable to interact with gut associated lymphoid tissue (GALT) immune cells improving the efficiency response and the intestinal permeability parameters. It is possible that by indirect way probiotics can contribute to muscle repair process, via immune cells activity (neutrophils and macrophages number and function), lowering the time spent with repairing process. However, from a scientific perspective, studies in experimental models with purpose to investigate the action of probiotics in muscle tissue are required to confirm this hypothesis, after these clinical studies are recommended to investigate the applicability of the results.

In relation to the consumption of probiotics in case of injury, a recommended dose is not clear, but in some studies related to fatigued athletes *Lactobacillus acidophilus* has been administered in a dose of 2×10^{10} colony-forming units (CFU)/day, *Bifidobacterium longum* (2.0×10^{8} CFU/day) for reducing the respiratory symptoms and infection duration in rugby players and in treated animals *Lactobacillus plantarum* (10^{7} CFU/day) increases muscle mass and has an anti-fatigue effect [79]. The probiotics genus most recommended in the field of sports nutrition are the *Lactobacillus* and *Bifidobacterium*, the dose of consumption in athletes is $\geq 10^{10}$ CFU [77], consumed in fermented foods, such as yogurt and kefir, or as dietary supplements.

Conclusions

An increase of 10 to 15% of the estimated energy requirement (EER), from 200 to 500 Kcal maximum could be beneficial in the recovery process of muscle injury; the caloric restrictions are not recommended, and it must be maintained an energy balance in accordance to the requirements of the healing process; also the diets with high-energy intake could be not beneficial especially in athletes for the increase of fat body mass and changes in body composition, these could delay the return to play.

In an event of injury involving immobilization and reduction of physical activity, it is important to avoid the anabolic resistance of muscle and the increase of the reactive species of nitrogen and oxygen, producing the proteolysis of the skeletal muscle. In accordance with the above, the recommendation of protein intake in the injured athlete should be adjusted from 1.6 g/kg/day to 2.5 g/kg/day of BM (total body mass), in order to maintain muscle mass; this contribution should be guaranteed from 4 to 6 meal times and with a consumption of 20–35 g of fast digesting protein, high-quality sources, and high-leucine content foods as dairy, meat, egg, whey protein, and soy.

The injured athlete must maintain a balanced diet with an adequate supply of antioxidants and anti-inflammatory compounds, the consumption of the Recommended Dietary Allowance (RDA) or the Adequate Intake (AI), through food (high consumption of fruits, vegetables, and both animal and vegetal sources of omega 3 fatty acids) could improve the inflammatory response, which is a normal response within the process of recovery of injured tissue.

The use of element probiotics, especially the *Lactobacillus* and *Bifidobacterium* strains in a daily dose of $\geq 10^{10}$ CFU, should help in repairing stage of injury to turning fast the process of muscle repair by immune cells action (granulocytes and phagocytes); however, more studies are required to confirm this hypothesis.

It is necessary to carry out clinical studies with injured athletes and determine directly how the consumption of nutrients and elements such as probiotics can influence the recovery processes of injured athletes, according to the literature there is little research in this area of sports nutrition.

Abbreviations

AI: Adequate intake; BM: Total body mass; CFU: Colony forming units; CK: Creatine kinase; CON: Placebo supplementation; CoQ10: Coenzyme Q10; CSA: Cross sectional area; EAA: Essential amino acids; ECM: Extracellular matrix; FGF: Epidermal growth factor and fibroblast growth factor; GALT: Gut associated lymphoid tissue; GPX: Glutathione peroxidase; HBO: Hyperbaric oxygen therapy; HEB: High energy balance; HMB: β-hydroxy β-methylbutyric acid; ISSN: International Society of Sport Nutrition; LBM: Lean body mass; LDH: Lactate dehydrogenase; LEB: Lower energy balance; LEU: Leucine; MPS: Muscle protein synthesis; mTOR: Mammalian target of rapamycin; n-3FA: Omega 3 fatty acid; NO: Nitric oxide; NSAIDs: Nonsteroidal anti-inflammatory drugs; PDGF: Platelet-derived growth factor; RDA: Recommended dietary allowance; REE: Resting energy expenditure; RICE: Rest, ice, compression, and elevation; ROS: Reactive oxygen species; SOD: Superoxide dismutase; TGF: Transforming growth factor; VEGF: Vascular endothelial growth factor

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