NUTRACEUTICALS: THEIR ROLE IN IMPROVING SPORTS PERFORMANCE

Stefania D’Angelo and Domenico Tafuri

Department of Movement Sciences and Wellbeing, University of Naples “Parthenope”, Naples, Italy

Abstract
Athletes experience regular cycles of physiological stress accompanied by transient inflammation, oxidative stress and immune perturbations. In fact, during exercise, oxygen consumption in muscle can increase 15-fold, leading to free radicals production that impairs the antioxidant system. High concentrations of free radicals can be harmful to many cellular tissues, although some reactive molecules, such as hydrogen peroxide and nitric oxide may serve functions in cellular signaling and as secondary messengers in moderate concentrations. Nutritional support has the potential to partially mitigate exercise-induced changes without interfering with the signaling activities necessary for training adaptations. Athletes should avoid foods that may increase oxidative stress and increase foods that are higher in antioxidants. An example would be a diet rich in fruits and vegetables, which raises plasma levels of antioxidants and protects against many chronic diseases. Optimizing nutrition in combination with exercise is considered an established, effective ergogenic practice for athletic performance. In recent years, the nutraceutical industry has gone from a simple conceptual area in biomedical research to a value-added industry with a promising future. Nutraceutical substances are normally obtained from foods, plants or even microorganisms. They have the potential to treat or prevent diseases, especially chronic ones, to improve physical and mental health, to increase life expectancy and to combat the typical disorders of aging. In this paper, we expose existing evidence surrounding the efficacy of most common nutraceutical compounds in combination or not with exercise in relation to skeletal muscle mass, metabolism, and exercise performance.

Key words: nutraceuticals, nutrition, performance, sports.

Introduction
Paradoxically, besides many health benefits, intense exercise can induce cell oxidative damage. The skeletal muscle can produce free radicals or Reactive Oxygen Species (ROS). ROS production increases during aging, in some pathological conditions (D’Angelo et al., 2012; D’Angelo et al., 2013), but also during contractile activity. In fact, aerobic exercise augments oxygen consumption (especially by the contracting muscle) with an increase of 15-fold in the rate of whole body O2 uptake and an increase of more than 100-fold in the O2 flux in active muscles (Steinbacher & Eckl, 2015; Kawamura & Muraoka, 2018) Therefore, regular exercise leads to the up-regulation of the antioxidant defense mechanisms, in order to minimize the oxidative stress. During exercise, ROS production can be higher than the muscle antioxidant capacity (Fisher-Wellman & Bloomer, 2009). A nutritional support can have the partially mitigate exercise-induced oxidative alteration without interfering with the signaling activities necessary for training adaptations.

Recently, the concept of the presence, in daily consumption foods, of nutraceutical components is born; these are bioactive nutrients-based functional food, which provide important benefits for human health, not only in conservative terms, but above all preventive. The term "nutraceutical" was coined from "nutrition" and "pharmaceutical" in 1989 by Stephen De Felice, which defined nutraceutical as "a food (or part of food) that provides medical or health benefits, including the prevention and/or treatment of a disease" (Brower, 1998). These substances normally derive from foods, plants or even microorganisms. In table 1 are reported some nutraceuticals and foods containing them. They have the potential to treat or prevent diseases, especially the chronic ones, to improve physical and mental health, increasing life expectancy and combating typical aging disorders (Shinde et al., 2014; Aronson, 2017). While drugs can often have side effects, nutraceuticals are often safer, with minimal undesirable effects, in addition to a greater bioavailability compared to conventional drugs. However, it is advisable to reduce the risk of "do-it-yourself" (Ruth & Izzo, 2017; Motti et al., 2018; D’Angelo et al., 2019). Among nutraceuticals related foods, in addition to yogurt, there are above all fruit and vegetables which are rich in antioxidants as polyphenols. Leutin, useful for sight, is contained in spinach, cabbage, broccoli and eggs; curcumin in the curry and yellow saffron pigment. Isoflavones are present in legumes, resveratrol in the grape skin and in the wine. Furthermore, carotenoids, folic acid, melatonin, carnitine, omega-3 are also known (Minuz et al., 2017).

In sports, nutraceuticals can be useful, in addition to preventing and treating athletes’ typical ailments, also to improving their performance (Rothschild & Bishop, 2019).

Some nutraceuticals and their effects on sports performance will be described below.
**Discussion**

**Table 1.** Some *nutraceuticals* and foods containing them.

<table>
<thead>
<tr>
<th>Nutraceutical</th>
<th>Chemical constituent</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allicin</td>
<td>Diallyl disulfide, organic sulfur compound that belongs to indoles</td>
<td>Garlic (allium sativum), onions, shallots, Chinese chives, leeks</td>
</tr>
<tr>
<td>ɑ-Carotene</td>
<td>Vitamin A</td>
<td>Fruit and vegetables: Carrots, sweet potatoes, dark leafy greens, such as kale and spinach, romaine lettuce, pumpkin, cantaloupe, red and yellow peppers, apricots, oranges, tangerines, corn, avocado, various fruits and vegetables</td>
</tr>
<tr>
<td>Catechin</td>
<td>Flavanols (polyphenolic group)</td>
<td>Green and black tea (extracted from <em>Camellia sinensis</em>), chocolate, beans, citrus, apples, berries, apricot, cherry, grape, strawberry, peach</td>
</tr>
<tr>
<td>Curcumin</td>
<td>Hydroxycinnamic acid Derivative (polyphenolic group)</td>
<td>Turmeric root</td>
</tr>
<tr>
<td>Daidzein Genistein</td>
<td>Isoflavones</td>
<td>Soy beans, legumes, curreants, raisins</td>
</tr>
<tr>
<td>Folic acid</td>
<td>Vitamin B</td>
<td>Hen eggs, goat liver, cereals, pulses, green leafy vegetables, asparagus, beets, citrus fruits</td>
</tr>
<tr>
<td>Lactobacilli</td>
<td>Probiotics, prebiotics</td>
<td>Yogurt, dairy applications</td>
</tr>
<tr>
<td>Bifidobacteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lycopene</td>
<td>Caroteinoid</td>
<td>Tomatoes, watermelon, grapefruit, sweet red peppers, pensimmon, asparagus, red cabbage, mangoes, pink grapefruit, guava, papaya</td>
</tr>
<tr>
<td>Omega 3 fatty acids</td>
<td>Polysaturated fatty acids (PUFA)</td>
<td>Sardines, salmon, tuna, halibut, and other seafood such as algae and krill; in lake trout, in some plants, in nut oils, flax seed</td>
</tr>
<tr>
<td>Policosanols</td>
<td>Aliphatic alcohols</td>
<td>Sugar cane, in beeswax, potatoes, rice bran</td>
</tr>
<tr>
<td>Quercetin</td>
<td>Flavonoid (polyphenolic group)</td>
<td>Leafy vegetables, broccoli, red onions, peppers, apples, grapes, black tea, green tea, some fruit juices, red wines, black berries</td>
</tr>
<tr>
<td>Resveratrol</td>
<td>Stilbene (polyphenolic group)</td>
<td>Red grapes (and thus red wine), peanuts, berries</td>
</tr>
<tr>
<td>Retinol</td>
<td>Vitamin A</td>
<td>Animals: Beef liver, lamb liver, liver sausage, cod liver oil, king mackerel salmon, bluefin tuna, goose liver pâté, goat cheese, butter, eggs</td>
</tr>
<tr>
<td>Selenium</td>
<td>Mineral</td>
<td>Tuna, shellfish, tofu, shrimp, mushrooms, walnuts, peas, beef, whole wheat pasta</td>
</tr>
</tbody>
</table>

1. **Omega-3** are polyunsaturated fatty acids with more than one carbon-carbon double bond in their backbone. These essential nutrients can be found in fish such as sardines, salmon, tuna, halibut, seafood, algae and krill, and in lake trout, in some plants, and in nut oils. Recent human studies demonstrate that they can influence not only the exercise and the metabolic response of skeletal muscle, but also the functional response for a period of exercise training. In addition, their potential anti-inflammatory and antioxidant activity may provide health benefits and performance improvement especially in individuals who practice physical activity (Gammone et al., 2018).
Six months of supplementation (3.36 g/day) resulted in an increased muscle mass (+3.6%) and strength (+4%) (Smith et al., 2015). Another study concerning muscle recovery and soreness after performing eccentric biceps exercises displayed that seven days of 3 g/day □-3 integration can decrease post-exercise muscle damage and soreness (Jouris et al., 2011). Omega-3 can probably improve athletic performances, through a modulation on cell membranes’ permeability and on insulin sensitivity, which makes the muscle cells more permeable to necessary nutrients, such as glucose and amino acids. 21-days □-3 integration in humans was reported to enhance muscle strength and neuromuscular recruitment following exercise training programs (Lewis et al., 2015). Omega-3 integration was also demonstrated to reduce muscle soreness and maintain muscle function following eccentric exercise-induced muscle damage. The effectiveness of consuming a protein-based supplement containing 1546 mg of □-3 twice daily was observed on muscle soreness, jump performance, and psychological well-being in 20 professional Rugby Union players (Black et al., 2018). The increasing intake of □-3 by taking more fish or supplements is a strategy that could be applied to this fraction of population in order to be an ergogenic aid that improves training and sports performance at low cost and with little risk.

2. Policosanols are natural substances composed of a mixture of long chain linear aliphatic alcohols (octacosanol, tetracosanol, and others). They are particularly present in waxy substances of sugar cane, in beeswax, potatoes, rice bran and equipped with antioxidant and anti-aggregation properties. The main benefit of their consumption concerns the total cholesterol and low-density lipoprotein levels decreasing (Askarpour et al., 2016). Policosanols are also promoted as supplements to improve athletic performance, but in this case there aren’t serious studies to support this claim. They have been used some decades ago by Cuban athletes who called them Preparadoparaganar (Prepared to win) a product that contained them. An early study reported that 1000μg of octacosanol significantly improved grip strength and reaction time in response to a visual stimulus (Saint-John, 1986). Another study found that octacosanol integration reduced body fat in athletes. However, limitations of this study included the lack of dietary control, lack of blind control and athletes involvement from different sports backgrounds in placebo group and in ones treated with supplement (Cockerill&Bucci, 1987).

3. Probiotics are those microorganisms (mostly bacteria) which, when ingested, as part of a food or supplement, survive, and perform beneficial functions to health. The intake of yoghurt and fermented probiotic milks is very advantageous for athletes, especially due to the immune-protective activity exercised by these bacteria, useful in case of particularly intense workouts to reduce the overtraining risk, which could lead to a drop in performance.

These bacteria also improve modulating the post-workout inflammatory states and preventing possible infections and disorders of the gastrointestinal tract that could occur during some sports activities. Probiotics also get better nutrient absorption, thus improving energy yield, and recent studies report that with probiotics integration can induce positive effects in modulating muscle inflammation, thus facilitating the recovery phase (Dalton et al., 2019). Probiotics are well tolerated in athletes; however, it is difficult to reproduce the results of studies conducted with athletes from around the world. Differences were found between the various studies which may results from causes such as the use of different probiotic or multilayer strains and the time and dose of intake, together with the use of different cohorts (Leite et al., 2019). Clark and Mach reported that the recommended diets for athletes probably influence intestinal microbiota by reducing biodiversity due to poor intake of dietary fiber (Clark& Mach, 2016).

4. Polyphenols. Human diets are rich in polyphenols; Western populations consume about 1-2 g/day of polyphenols. The most important polyphenols food sources are fruit and vegetables, green and black tea, red wine, coffee, chocolate and extra virgin olive oil; apples, grapes, pears and berries generally contain high amounts of polyphenols (200-300 mg per 100 g). Herbs and spices, nuts and algae are also potentially relevant sources of polyphenols, depending on culinary habits. Polyphenols have various biological activities(D’Angelo et al., 2012; D’Angelo et al., 2017; D’Angelo et al., 2019; Martino et al., 2019)and in particular, they are antioxidants (D’Angelo et al., 2009; Zappa et al., 2010; D’Angelo & Sammartino, 2015). To date, many studies concern polyphenols and physical exercise. The effects of different polyphenols have been studied in a wide range of operating conditions, using a variety of integration, timing and dosage strategies. Until a few years ago, despite the active search for "natural" extracts, rich in polyphenols, limited information was available and, in some cases, inverse effects were suggested (D’Angelo, 2019; Somerville et al., 2017; Malaguti et al., 2013).

- Black cherry is a special fruit because it contains the highest concentration of anthocyanins with an average of 30-40mg per 100g of fruit. Daily intake of tart cherries may attenuate inflammatory and oxidative responses to exercise-induced muscle damage, leading to faster recovery after exercise bouts (Coelho et al., 2015).
- Tart cherry (TC) juice attenuates pain and accelerates strength recovery after exercise and decreases blood markers of inflammation/oxidative stress. These improvements occur in both strength and endurance exercise. Excessive inflammatory/oxidative stress during single-day intense training/competition or multiday tournaments may delay return to peak form. In this stage, where recovery (not adaptation) is the priority, TC may be beneficial.
Timing and dosage vary widely, but most studies use 8 to 12 oz twice a day, 4- to 5-d loading phase before the event, and 2 to 3 d after to promote recovery. Therefore, for an athlete who has already peaked in training and looking to improve recovery and faster return to competition, TC may be beneficial (Vitale et al., 2017). Promising results have been observed in studies on terrestrial resistance sports, whereas water polo athletes have shown no positive effects with tart cherry juice supplementation (McCormick et al., 2016). Probably, the mechanical stress induced by the water polo activity is lower than the endurance race or the effort cycling, as a result of the sustained and intermittent character of the activity carried out (Cook & Willems, 2019).

- Curcumin is the main curcuminoid present in the curcuma, a vegetable alkaloid derived from hydroxycinnamic acid. Experimental evidences suggest that under some conditions curcumin limits the production of pro-inflammatory molecules and therefore has a similar anti-inflammatory activity as some of the common non-steroidal anti-inflammatory drugs, but without many of the side effects, such as gastrointestinal discomfort and cardiovascular complications. Some investigations suggest that curcumin may be effective in controlling inflammation and oxidative stress induced by delayed onset muscle pain (DOMS). Integration with curcumin (2.5 g/day twice a day) relieves DOMS, guarantees a better recovery of muscle performance and also promotes muscle regeneration. Data suggest that a 150 mg dose of curcumin can induce antioxidant, anti-inflammatory and analgesic effects on DOMS (Nakhostin-Roohi et al., 2016).

- Green tea (Camilla Sinensis) extract is rich in polyphenols, with a flavonoid structure. It contains high amounts of caffeine, catechin, theobromine and theophylline, with antioxidant properties and ability to increase energy expenditure by stimulating the thermogenesis of brown adipose tissue (Sellami et al., 2018). The integration of green tea has been recommended as a strategy to improve recovery of physical activity due to the high antioxidant and anti-inflammatory potential of catechin, and it has been shown that the combination of green tea with caffeine is able to significantly increase energy expenditure by 24 hours and fat utilization in active individuals (Panza et al., 2008). Supplementation with green tea extract prevents oxidative stress induced in sprinters and it does not seem to hinder training adaptation in antioxidant enzyme system. On the other hand, neither prevention of exercise-induced muscle damage, nor an improvement in sprint performance is observed after green tea extract administration (Jowko et al., 2015).

- Myrtuscomminus L. is a species of Myrtaceae family, native to the Mediterranean basin and many phenolic compounds have been identified in its berries as phenolic acids (gallic acid, caffeic acid, syringic acid, vanillic acid and ferulic acid), flavonoids (quercetin, myricetin) and hydrolysable tannins (gallotannins). Myricetin and its glycosidic derivatives are the main constituents of myrtle berries. Recent studies show the benefits of myrtle fruit as integration in sports. Slimeni et al. showed that 4 weeks of myrtle supplementation (3.4 mg / kg / day) can increase anaerobic performance, serum proteins and iron and reduce triglycerides, in moderately trained athletes (Slimeni et al, 2017).


