Antioxidants

Maximizing the Training Effect

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Introduction

Antioxidants form a front line defense against cell damage caused by free radicals, which are involved in muscle, joint and tendon damage and inflammation, degenerative arthritis and even in the aging process. The use of antioxidants can reduce free radical damage that occurs when we exercise[1] and also can attenuate the ongoing damage to injured tissues caused by free radicals, thus accelerating the healing process.

Because of their useful and sometimes dramatic effects, I include a comprehensive antioxidant in my nutritional supplement lineup.

Antioxidants, such as vitamins C and E (see under Vitamins below), selenium, green tea, reduced glutathione and N-acetyl-cysteine (NAC) can play an important role in reducing inflammation and fatigue, decreasing tissue damage, and in both preventing and treating injuries.

Various antioxidants, such as vitamin E, have been found to be useful in the treatment of some forms of arthritis[2] and in dealing with the oxidative stress of exercise.[3] As well, oxidative damage has been shown to contribute to the pathogenesis of injuries and arthritis, and the use of antioxidants, such as NAC,[4] shown to have therapeutic value for reducing endothelial dysfunction, inflammation, fibrosis, invasion and cartilage erosion.

A recent study found that a combination of two antioxidants, selenomethionine and epigallocatechin-gallate (the main antioxidant in green tea extract), had beneficial effects on catabolic and anabolic gene expression of articular chondrocytes.[5] The authors of the study concluded that: *"Our data provide insights into the mechanisms whereby ECGg and selenium modulate chondrocyte metabolism. Despite their differential mechanisms of action, the 2 compounds may exert global beneficial effects on articular cartilage."*

The Line-up

Vitamin C

Vitamin C is essential to proper collagen synthesis, and this is evident in the vitamin C deficiency disease scurvy, in which the collagen fibers synthesized in the body cannot form fibers properly, thus resulting in lesions, blood vessel fragility and poor wound healing.

Vitamin C has been shown to have some anticatabolic effects that likely involves decreasing exercise induced cortisol but may also have some effects through its antioxidant action. Conversely, some of the anticatabolic effects of antioxidants may be mediated through a decrease in cortisol.

Antioxidants may be of some use in training induced muscle ischemia and injury. Research shows that exercise can affect muscle tissue adversely by increasing the formation of free radicals. These free radicals then can lead to muscle fatigue, inflammation and muscular damage.[6] During normal conditions free radicals are generated at a low rate and neutralized by antioxidant enzymes in the liver and skeletal muscle and other systems. Unfortunately, the increase in free radicals caused by exercise accompanies a simultaneous decrease in the supply of antioxidants to handle them. Vitamin E, for instance, can be decreased severely by training, thus depleting muscle of its major antioxidant force.[7]

A study examined the potential protective effect of pretreatment with corticosteroids or antioxidants (ascorbic acid or allopurinol) in rabbits with reperfusion-induced damage to skeletal muscle after ischemia.[8] In this study, four hours of limb ischemia induced by a pneumatic tourniquet, followed by reperfusion for one hour, caused a considerable amount of ultrastructural damage to the anterior tibialis muscles accompanied by a rise in circulating creatine kinase activity. Pretreatment of animals with depomedrone by a single 8 mg bolus injection led to a preservation of the anterior tibialis structure on both light and electron microscopy. High-dose continuous intravenous infusion with ascorbic acid (80 mg/hr) throughout the period of ischemia and reperfusion also preserved skeletal muscle structure, although allopurinol in various doses had no protective effect.

These data are fully compatible with a mechanism of ischemia/reperfusion-induced injury to skeletal muscle, involving generation of oxygen radicals and neutrophil sequestration and activation. They also indicate that damage to human skeletal muscle caused by prolonged use of a tourniquet is likely to be reduced by simple pharmacological interventions.

Vitamin C is necessary for collagen synthesis and is a strong antioxidant with beneficial effects on pro-inflammatory cytokines.[9] Research on vitamin C shows that it may have important effects in reducing pain and inflammation secondary to exercise. In one study, 400 mg daily of vitamin C reduced post exercise pain and inflammation.[10] Vitamin C is involved in the enzymatic hydroxylation of proline to form 4-hydroxyproline, an amino acid that is an integral part of collagen and elastin.

Coenzyme Q10 (ubiquinone-10)

Coenzyme Q10 acts as an electron carrier of the respiratory chain in mitochondria. As well, it has been shown that the reduced form of coenzyme Q10 is an important physiological lipid-soluble antioxidant and scavenges free radicals generated chemically within liposomal membranes.[11,12] It also has been shown that vitamin E and ubinone increase physical working capacity of experimental animals.[13]

Generation of free radicals and subsequent lipid peroxidation have been proposed to contribute to delayed tissue damage. One study has found that ascorbate and ubiquinol levels were decreased after trauma.[14] In this study, changes in tissue levels of ubiquinol, but not ascorbate reflected the degree of trauma. The authors suggest that ubiquinol levels may provide a useful marker of the oxidative component of the secondary injury response.

Zinc

Zinc deficiency in humans is widespread[15] and athletes may be particularly prone to lower plasma zinc levels.[16] Zinc is a constituent of more than a hundred fundamentally important enzymes, and so zinc deficiency has many negative effects on almost every body function.[17] As well, zinc deficiency can adversely effect the reproductive hormones and as such impair athletic efforts.[18]

Zinc deficiency adversely affects protein synthesis. In one study the effects of zinc deficiency in rats, on the levels of free amino acid in urine, plasma and skin extract were investigated.[19] Zinc deficiency adversely affected skin protein synthesis. Especially where a deficiency may be present, supplemental zinc has resulted in an increase the secretion of growth hormone and IGF-I,[20] and testosterone[21] and to raise plasma testosterone and sperm count.[22],[23]

Magnesium

Magnesium supplementation has been shown to increase protein synthesis and strength.[24] In another study the authors felt that insulin sensitivity can be improved by reduction of excessive body weight, regular physical activity and, possibly, by correcting a subclinical magnesium deficiency.[25]

Calcium

Calcium permits the contractile filaments of the muscle cell -actin filaments and myosin filaments- to associate and produce the force that generates movement. When the nerve cell innervating a muscle cell signals that cell to contract, calcium is released from the sarcoplasmic reticulum into the region of the contractile filaments, thereby permitting contraction to occur. In one study calcium was shown to be effective in prolonging time of onset of fatigue in striated muscle.[26]

Several studies have shown that calcium plays a key role in body weight regulation and especially on fat metabolism (with possible effects on lipolysis, fat oxidation, lipogenesis, energy expenditure, and appetite suppression) and thus is a useful supplement for those looking to decrease weight and body fat.[27,28,29,30,31,32,33,34,35,36]

For example, Zemel et al. (2002) looked at the effects of calcium supplements on obese adults who were dieting. They found that a high-calcium diet (1200-1300 mg/day) resulted in greater weight and fat loss in humans compared to a low-calcium diet (400-500 mg/day).

Another study published in November, 2004 found that a high intake of calcium may hinder weight and fat regain.[37] The study found that after putting mice on a low calorie diet and producing weight and body fat loss, that those on a low calcium diet regained their weight after 6 weeks. However, for those on a high calcium diet it was a different story. They found that the high calcium diets produced significant increases in lipolysis, decreases in fatty acid synthase expression and activity, and reduced fat regain. They also found that increasing calcium through the use of dairy products had significantly greater effects on fat regain.

Chromium

It has been shown through various studies that chromium is an essential element involved in carbohydrate and lipid metabolism. Since the need for chromium increases with exercise,[38] and modern refined foods are low in chromium, there may be a need for chromium supplementation in athletes and other active people,[39] and especially in those wanting to lose weight and/or improve body composition.[40]

Insufficient dietary chromium has been linked to maturity-onset diabetes and cardiovascular diseases, with supplemental chromium resulting in improvements of risk factors associated with these diseases.[41,42,43]

One of the most frustrating aspects of being overfat is that your body has become conditioned to converting excess calories, especially if combined with high carbohydrate intake, into body fat. Part of the problem with this fat conditioning involves insulin – as you gain more body fat you become more insulin resistance so that you need more insulin to do the same job as when you had less body fat. This increase in insulin decreases your ability to use body fat as fuel, and stores more energy as body fat. The end result is a fatter you.

Chromium helps to increase insulin sensitivity and thus your body's ability to burn off body fat as a preferred fuel, and decreases body fat production. Along with its effects on muscle, chromium picolinate has been shown to have significant effects on body composition.[44,45,46]

Although most diets just barely provide the RDA for chromium, for many it's not enough to make up for daily losses, especially if they exercise.

Chromium and Conjugated Linoleic Acid (CLA)

It's been shown that combining chromium with CLA (see below for information on CLA) enhances insulin sensitivity and body composition even more when used together. A recent study found that CLA alone lowered body weight, total body fat mass, and visceral fat mass, the last of which decreased further with the combination of CLA and Chromium.[47]

Potassium

Potassium is one of the essential dietary minerals. While most diets supply an adequate amount of potassium, athletes may have increased needs since it is one of the electrolytes lost in sweat. While it is important for athletes to replace the increased electrolytes lost due to sweating, it is especially important to replace potassium.

Even mild potassium deficiency can lead to fatigue and decreased performance,[48] while a significant deficiency can lead to cardiac problems. Muscular fatigue is manifested by a decline in force- or power-generating capacity and may be prominent in both submaximal and maximal contractions. Disturbances in muscle electrolytes play an important role in the development of muscular fatigue. Unfortunately, surprisingly little research has been carried out to investigate the effects of exogenous potassium on training intensity and muscle hypertrophy.

Studies with isolated animal muscle fibers have shown that potassium may help alleviate muscle fatigue. KCl- or caffeine-induced release of Ca2+ from intracellular stores has been shown to decrease fatigue by reversing long-lasting interference in excitation-contraction coupling.[49]

Since some studies have implicated the decline of the intracellular to extracellular potassium gradient and extracellular K+ accumulation during activity is an essential factor of muscle fatigue,[50] it might be argued that excessive potassium accumulation at the surface of the muscle cell might increase fatigue. A recent study investigated the role of K+ in muscle fatigue by testing whether an increased extracellular K+ concentration in unfatigued muscle fibers caused a decrease in force similar to the decrease observed during fatigue.[51] The authors concluded that exogenous potassium does not cause accumulation of K+ at the surface of the sarcolemma that is sufficiently large to suppress force development during fatigue.

It has been shown that potassium deficiency can result in lower GH and IGF-I levels and that potassium replacement restores these levels. The problem appears to be at the pituitary level rather than the muscular level since the use of GHRH did not correct serum levels.[52] As well a recent study has shown that potassium deficiency inhibits protein synthesis.[53]

Alpha Lipoic Acid

Alpha lipoic acid (ALA) has potent antioxidant properties intrinsically and secondary to its ability to increase levels of intra-cellular glutathione, and its ability to recycle other antioxidants such as vitamin C, vitamin E and glutathione.[54,55,56,57,58] ALA and glutathione have been shown to have significant effects in decreasing mercury toxicity in the body.[59]

Alpha lipoic acid also has significant anti-inflammatory properties and has been shown to inhibit IL-1, a proinflammatory cytokine and also inhibit the synthesis of PGE2 by inhibiting COX-2 activity.

This latter mode of action, along with similar effects from CLA, simulates the anti-inflammatory effects of the present class of NSAIDS such as Celebrex, Advil, Aleve, etc. As well, EFA+ contains fish oil with substantial amounts of DHA and EPA, which has also been shown to have effects similar to the anti-inflammatory prescription and OTC drugs.[60]

ALA also is useful because of its actions on decreasing both the pro-inflammatory cytokines[61,62] and because of its effects on decreasing secondary cortisol elevations.

It has been shown to inhibit cross-linking among proteins, a process that contributes to the aging process in the body and especially in collagen-heavy tissues such as skin. Alpha-lipoic acid activates a collagen-regulating factor known as AP-1 that turns on enzymes that digest glycation-damaged collagen and, thus, make the skin more supple and youthful looking.

Besides having potent antioxidant and anti-inflammatory effects, ALA also has significant anabolic effects secondary to its beneficial effects on insulin sensitivity and growth hormone and IGF-I secretion, all factors involved in maintaining, repairing and regenerating musculoskeletal tissues.[63,64,65,66]

The bottom line is that antioxidants can decrease unproductive cell damage, help the recovery process, help to prevent injuries, decrease fatigue, and play an important role in maximizing the training effect and subsequently improving performance and body composition.

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