

## Attenuation of short-term increased oxidative stress during martial arts competitions, and benefits of micronutrients for martial art athletes

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### Abstract

Interest and participation in competitive Martial Arts such as Taekwondo, Karate, Kung Fu, Aikido, and Tai Chi is growing in children, adolescent as well as in adults in the USA and worldwide. Competitive Martial Arts require daily training weeks and sometimes, months prior to the start of a competition or tournament. The training period could be for a few hours daily over a period of one to six months with one or two days for every one week for rest and recovery. The types and extents of injuries after competition depend upon the form of Martial Arts and the type of physical contact. They include muscle, joint, head and neck, groin, upper and lower extremities, and soft tissues. Some acute injuries can be taken care of at home and the injured may recover quickly. Some injuries may require hospitalization and even surgery; while others may take longer period to recover and require stoppage in training. The training involves daily exercises during which moderate levels of reactive oxygen species (ROS) are produced. ROS activates a transcriptional factor Nrf2 (nuclear factor-erythroid 2-related factor 2) which enhances the levels of antioxidant enzymes; and thereby, reduces oxidative stress. Because of this observation, some investigators have suggested that supplementation with micronutrient and antioxidant compounds is not necessary for reducing injuries and improving the rate of healing from injury. Appropriate diet recommended for Martial Arts athletes are sufficient to reduce oxidative damage and protect against injuries that occur during Martial Arts competitions. The use of a single antioxidant in reducing oxidative stress has produced inconsistent results in reducing the markers of oxidative stress. The limitations of such an approach are briefly discussed. This review has proposed a mixture of micronutrients which may reduce oxidative stress and improve performance in Martial Arts competitions. In addition, some beneficial effects of Martial Arts are also described.

**Keywords:** Oxidative stress; Martial Arts; Micronutrients; Health benefits

### 1. Introduction

Interest in Martial Arts is growing in children, adolescent as well as in adults worldwide. This sport can be recreational or competitive. The competitive Martial Arts require training before the start of any competition or tournament. The training period could be for a few hours daily over a period of one to six months with one or two days for every one week for rest and recovery. There are different types of Martial Arts which include Taekwondo, Karate, Kung-Fu, Aikido, and Tai Chi. Rate of the injury expressed as % of participants were 59% for Taekwondo, 51% for Aikido, 38% for Kung-Fu, 30% for Karate, and 14% for Tai-Chi (1). The types and extents of injuries depend upon the form of Martial Arts and types of physical contact (stand up versus ground games, kicking versus punching). They include muscle, joint, head and neck, groin, upper and lower extremities, and soft tissues (2, 3). Some acute injuries can be taken care of at home, and while some require hospitalization and/or surgeries; some of them recover quickly, while others can take longer period to recover and may require stoppage in training.

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Competitive Martial Arts require the athlete to have excellent strength and flexibility, focus and awareness, stamina, cardiovascular health, breathing, visual motor integration, and control of inner conflicts of fear, stress, and pressure. Coaches make sure their team members practice every day to achieve all the above requirements for a competitive Martial Artist. Like in all sports including Martial Arts, a healthy mind and healthy body are required for an optimal performance in a competitive setting.

Intestinal health is equally important for healthy mind and body because healthy intestines provide better absorption of food and micronutrients. The number of human cells are approximately 37 million, whereas the number of intestinal microbiota (bacteria, fungi, yeast and viruses) are approximately 38 million (4). Most of them are intestinal bacteria; many of which are beneficial bacteria while some are harmful bacteria. Beneficial bacteria produce small fatty acids during fermentation of fiber such as butyric acid which is important for intestinal health as well as acting as anti-cancer agents (5). These small fatty acids are not only essential for the intestinal health, but also for the improved immune and brain functions. Poor diet such as high sugar and fatty foods can increase the number of harmful bacteria in the intestine which produces pro-inflammatory cytokines that can damage all organs in the body. Supplementation with probiotics with prebiotics can maintain the balance in favor of beneficial bacteria. Also, an appropriate diet recommended for Martial Arts athletes would maintain composition of intestinal bacteria in favor of beneficial bacteria.

Extensive studies have been performed to evaluate oxidative stress during training and during competitive matches in Martial Arts athletes. The levels of the markers of oxidative stress did not significantly change while the markers of antioxidant defense system increased during training period which requires less intensive exercise. It is known that moderate exercise generates low levels of reactive oxygen species (ROS) which activates a nuclear transcriptional factor Nrf2 (nuclear factor-erythroid factor 2-related factor 2). Activated Nrf2 dissociates itself from Keap1- Cul1-Rbx1 complex located in the cytoplasm and migrates to the nucleus where it heterodimerizes with a small Maf protein and binds with ARE (antioxidant response element), leading to increased transcription of cytoprotective enzymes including antioxidant enzymes (6, 7). It has been reported that activation of Nrf2 decreases oxidative stress as well inflammation (8, 9). Certain antioxidants such as some antioxidant compounds, such as vitamin E and genistein (10), alpha-lipoic acid (11), curcumin (12), resveratrol (13, 14), omega-3-fatty acids (15, 16), glutathione (17), NAC (18), and coenzyme Q10 (19) activate ROS by mechanisms that are different from those by ROS. The antioxidant system constitutes not only antioxidant enzymes which are enhanced by exercise-induced ROS-mediated activation of Nrf2, but also antioxidant compounds, some of which are taken from the diet whereas some are made in body which were not evaluated in any Martial Arts athletes before and after competition. Increased oxidative stress during Martial Arts fights may reduce the levels of dietary and endogenous antioxidant compounds, measured after competition. The role of these antioxidant compounds in Martial Arts athletes during training, or before and after competitive matches have not been adequately investigated. Limited studies have produced inconsistent results (20-22).

Although no significant changes in the levels of markers of oxidative stress in the peripheral blood were observed in Martial Arts athletes, it remains unknown whether the brain of these athletes would reveal similar alterations. It is known that the brain consumes 20% of respired oxygen and produces free radicals during generation of energy by the mitochondria as by-products. It is proposed that during Martial Arts competitions, the athlete's brain may consume more than 20% of respired oxygen, the production of ROS may substantially increase compared to peripheral tissue. It is possible that the brain of these athletes may sustain more oxidative injuries during short days of Martial Arts competitions than the peripheral tissues. Such injuries can be attenuated by a mixture of micronutrients at appropriate dose and dose-schedules.

This review proposes that an appropriate diet together with an oral supplementation with a mixture of micronutrients a few days before and the day of matches may reduce the risk of soft tissue injury. It is suggested that taking the same proposed micronutrients after injury may enhance the rate of recovery of both the peripheral tissues and the brain. In addition, this review briefly describes potential benefits of Martial Arts in individuals of all ages.

### **1.1. Oxidative Stress in Martial Arts**

Intense exercise occurs in competitive sports during game time. It induces increased production of free radicals also referred to as reactive oxygen species (ROS) and reactive nitrogen species (RNS) derived from nitrogen. When the production of free radicals overwhelms the body's antioxidant defense system, oxidative stress occurs. Increased oxidative stress damages DNA, protein, and lipid in the cells, and if the damage is not fully repaired, chronic inflammation, which releases toxic chemicals such as pro-inflammatory cytokines, complement proteins, adhesion molecules, and free radicals, occurs. On the other hand, moderate exercise can activate a nuclear transcriptional factor Nrf2 which increases the transcription of genes for antioxidant enzymes such as glutathione peroxidase, catalase, and superoxide dismutase (SOD) which can protect against the small production of free radicals.

During the Martial Arts practices, it has been suggested that free radicals-induced activation of a nuclear transcriptional factor Nrf2 may prevent elevation of markers of oxidative stress. This is due to the fact that activation of Nrf2 enhances the levels of antioxidant enzymes such as glutathione peroxidase, catalase, and superoxide dismutase (SOD). Generally, the level markers of oxidative stress are monitored in the plasma after Martial Arts combat and no significant elevation of markers of oxidative stress has been found (23). A study reported that the blood levels of glutathione was higher and oxidized glutathione were lower at rest in middle-aged practitioners of a form of Korean Martial Arts called Soo Bahk Do, compared to those who were sedentary (24). In another study, it was suggested that the activities of catalase and superoxide dismutase increased while the level of malonaldehyde (MDA) decreased after 3 months of specific training in elite karate practitioners. This study showed contradictory results because increased activities of antioxidant enzymes were observed in the presence of elevated level of a marker of oxidative stress (25). This contradictory result could have been due to a large variation in the average of each parameter.

The peripheral markers of oxidative stress may not reflect the levels of oxidative stress in the brain. It is likely that despite no significant changes in markers of oxidative stress, the brain may have higher levels of these markers which could affect brain function. The main reason for this possibility is that the brain takes up 20% of respired oxygen at rest, 98% of that is used by the mitochondria to generate energy (26). Free radicals are formed as a by-product during processes of generation energy. The brain may take more than 20% of respired oxygen during Martial Arts competitions. The intake of more oxygen during competition would produce more free radicals which can damage the brain more than the peripheral tissues such as the muscle or the joints. The brain is very vulnerable to damage produced by free radicals, because it consumes high levels of oxygen which produce an extensive amount of free radicals, but it has low levels of antioxidant defenses and high contents of polyunsaturated fatty acids which is easily damaged by free radicals (27). Since, antioxidants neutralize free radicals, it may be necessary to provide an extra amount of a mixture of antioxidants before and after competitive Martial Arts events to protect the brain against free radical-induced damage. Such a strategy may also improve the rate of recovery of the muscle and joints.

## 1.2. Antioxidants use in Martial Arts Athletes

Taekwondo is a traditional Korean military-based Martial Arts. Supplementation with polyphenols in combination with exercise facilitates weight loss and improve aerobic capacities in Taekwondo athletes (28). Short-term supplementation with 2000 mg/day vitamin C (ascorbic acid) and 1400 IU/day vitamin E (alpha-tocopherol) for 4 days (3 days before and on day of competition) effectively reduced exercise-induced tissue damage and inflammatory response during and after four successive Taekwondo matches. Levels of myoglobin and hemolysis were lowered in vitamin treated Taekwondo athletes compared to placebo group (29). In contrast to these observations, oral supplementation of vitamin C alone or vitamin C and vitamin E together prevented cellular adaptation to endurance training and reduced mitochondrial biogenesis (20, 21). Others reported that supplementation with vitamin C and vitamin E failed to interfere with cellular adaptation to endurance training (22). Supplementation with Coenzyme Q10 at a dose of 300 mg/day for 20 days reduced muscle injuries in Japanese Kendo students (30). Another reported that coenzyme Q10 treatment attenuated exercise-induced muscular injury (31).

The administration of one or two antioxidants may not be optimally effective in reducing oxidative stress in Martial Arts athletes during the competition period. Some of them are described here:

- Administration of a single antioxidant in a high internal oxidative environment of Martial Arts athletes during matches would be oxidized, which then would act as a pro-oxidant rather than as an antioxidant.
- Different antioxidants are distributed differently in different organs and in the sub-cellular compartments of the same cells, all of which must be protected. Administration of a single antioxidant cannot accumulate in all parts of the cell in sufficient amounts to provide adequate protection against oxidative damage.
- Vitamin E is more effective scavenger of free radicals in reduced oxygen pressure, whereas beta-carotene and vitamin A are more effective in higher oxygen pressure of the cells (32). Therefore, administration of one antioxidant may not provide adequate protection of all organs and all sub-cellular compartment of the cell against oxidative damage.
- An elevation of both antioxidant enzymes and dietary and endogenous antioxidant compounds are needed to achieve maximal protection against oxidative and inflammatory damages, because they act by different mechanisms. Antioxidant compounds neutralize free radicals by donating electrons to those molecules with unpaired electrons, whereas antioxidant enzymes destroy H<sub>2</sub>O<sub>2</sub> by catalysis, converting them to harmless molecules such as water and oxygen. Administration of a single antioxidant cannot achieve this goal.
- Administration of a single antioxidant cannot protect both the aqueous and lipid compartments of the cell against oxidative injury.

- Different antioxidants increase the production of different protective proteins in the cells by altering the expression of different microRNAs (33). For example, some antioxidants such as an analog of curcumin can activate Nrf2 by upregulating miR-200a, which inhibits its target protein Keap1, whereas others can activate Nrf2 by downregulating miR-21, which binds with 3'-UTR Nrf2 mRNA (34). Thus, different antioxidants activate Nrf2 (Nuclear Factor-Erythroid-2- Related Factor 2) by different mechanisms. Administration of a single antioxidant cannot accomplish the above objective.

### **1.3. Proposed Micronutrients Mixture for Martial Arts Athletes during Competitions**

To simultaneously reduce oxidative stress and chronic inflammation, it is essential to increase the levels of antioxidant enzymes and antioxidant compounds at the same time. A mixture of micronutrients which can reduce these cellular defects at the same time in Martial Arts athletes a week before and after matches was suggested. This mixture includes vitamin A (retinyl palmitate), vitamin E (both d-alpha-tocopherol acetate and d-alpha-tocopheryl succinate), natural mixed carotenoids, vitamin C (calcium ascorbate), vitamin D3, all B-vitamins, coenzyme Q10, alpha-lipoic acid, N-acetylcysteine (NAC), resveratrol, curcumin, quercetin, green tea extract, and minerals selenium and zinc. This micronutrient mixture has no iron, copper, or manganese. Although these trace minerals in tiny amounts are essential for the growth and survival, slight excess of free iron and copper can increase the risk of chronic diseases, because these trace minerals when combined with vitamin C produce extensive amounts of free radicals and they, in the presence of antioxidants, are rapidly absorbed. This micronutrient mixture also has no heavy metals such as vanadium, zirconium, and molybdenum, because increased levels of these heavy metals are neurotoxic. There are no methods of elimination of either trace minerals or heavy metals from the body; therefore, taking them with a micronutrient mixture could be harmful after a prolonged consumption. In addition to these micronutrients, branched amino acids such as leucine, isoleucine, and valine were added to the above micronutrient mixture to improve muscle functions in Martial Arts athletes during competition.

#### *1.3.1. Dose schedule*

Generally, micronutrient supplements are recommended to be taken once-a-day. This review has recommended consuming daily dose of a micronutrient mixture twice-a-day (half in the morning and another half in the evening with a meal). Biological half-lives of micronutrients in the blood vary depending upon their solubility. Generally, half of the micronutrients are eliminated from the blood by the evening and another half by the next morning, causing high levels of fluctuation in the amounts of micronutrients in the blood. It has been demonstrated that a difference in the levels of antioxidants induced marked alterations in the expression of genes (35). Daily expression of such alterations in gene expression may lead to an error causing gene mutation. Taking daily dosages divided into two doses can reduce the level of fluctuation of antioxidants in the blood, and thereby, reduce the chances of a gene mutation.

### **1.4. Likelihood of Success in Improving Performance of Martial Arts Athletes by a Mixture of Micronutrients**

It is highly likely that the proposed mixture of micronutrients would be effective in reducing oxidative stress and soft tissue injuries, resulting into improved performance during Martial Arts competitions. This possibility is supported by two clinical studies with a mixture of micronutrients. For example, administration of multiple micronutrients reduced the risk of cancer in men (36) and prolonged the time for initiating the anti-viral therapy in HIV infected patients (37).

### **1.5. Beneficial Effects of Martial Arts on Human Health:**

Karate training improves brain functions and neurocognitive action through a lifetime. Electrophysiological studies revealed improvement in neural efficiency, stress tolerance, working and muscle memory (38). Martial Arts improves cognitive functions in children and alert attention network in adults (39). It also reduces anxiety and depression among children and improves overall mental health (40). Intensive and sustained practice of Martial Arts such as Judo and Karate reduces the decline of age-related dynamics visual acuity (DVA), suggesting neuroplasticity of aging human brain (41). Taekwondo training programs enhanced physical fitness, leading to improvement in depression and physical characteristics of elderly participants (42). The correlation with dementia risk factors was based on improved cognitive functions, and reduced level of beta-amyloids which are associated with Alzheimer's disease (42). Practice of Tai Chi produces beneficial effects such as: improvements in blood pressure, glycemic control, quality of life, and peripheral nerve conduction; reduction in oxidative stress; and improvement in the immunity of patients with diabetes Type II (43). The Kung Fu training produced beneficial effects which include: the reduction of blood pressure, balancing of blood glucose levels, overall improvement in quality of life, ability to balance, peripheral nerve conduction, and improvements in the immune functions of patients with diabetes Type II (44, 45).

## 2. Conclusion

Interest in Martial Arts is growing in the USA and worldwide. Common injuries after Martial Arts competitions include muscle, joint, head and neck, groin, upper and lower extremities, and soft tissues. During training only moderate levels of reactive oxygen species (ROS) are produced. ROS activates a transcriptional factor Nrf2 which enhances the levels of antioxidant enzymes which reduce oxidative damage. Because of this observation, some investigator suggested that supplementation with antioxidant compounds is not necessary for reducing injuries and improving the rate of healing. The use of a single antioxidant in reducing oxidative stress has produced inconsistent results in decreasing the markers of oxidative stress. The limitations of such an approach are briefly discussed. Appropriate diet recommended for Martial Arts athletes are considered sufficient to protect against potential injuries that occur during Martial Arts competitions and tournaments. This may not be sufficient for reduction in oxidative damage, improving the rate of recovery and above all, enhanced ability in performance. This review has proposed a mixture of micronutrients which may reduce oxidative stress and inflammation, enhance the rate of recovery from injury, and improve performance of Martial Arts athletes in competitions. Clinical studies should be performed to test the effectiveness of proposed micronutrient and antioxidant mixture. In addition, some beneficial effects of Martial Arts in humans are described.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

Tyler M Delarosa has no conflict. Kedar N Prasad is the Chief Scientific Officer of Engage Global Inc. of Utah. This company sells nutritional products to consumers.

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