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Commentary

Hormesis in Motion: Exercise-Induced Oxidative Stress and the Case Against Antioxidant Supplementation in Athletes

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Exercise has long been framed as a double-edged metabolic sword. Vigorous muscular contraction increases mitochondrial oxygen flux and generates Reactive Oxygen Species (ROS) at rates well above resting baseline, and for decades this was treated purely as collateral damage-a side effect to be neutralized with antioxidant pills. According to PubMed, this assumption has been substantially revised: high levels of ROS produced in skeletal muscle during exercise have been associated with muscle damage and impaired muscle function, which led to interest in supporting endogenous defenses with oral antioxidant doses as a strategy to reduce oxidative stress and improve performance. Yet the accumulated evidence now points in the opposite direction from what athletes and coaches often assume.

The core conceptual shift is hormesis: a biphasic dose-response in which a stressor that is damaging at high doses is adaptive-even necessary-at the lower doses encountered during normal training. Although ROS are associated with harmful biological events, they are also essential to the development and optimal function of every cell. Exercise-induced ROS are not simply noise in the system; they are signals. They activate redox-sensitive transcription factors and kinases that drive mitochondrial biogenesis, antioxidant enzyme upregulation, and improved insulin sensitivity. When athletes flood their tissues with exogenous antioxidants-particularly high-dose Vitamin C and Vitamin E-they risk silencing this very signal.

The empirical record bears this out. According to PubMed, a comprehensive review examining studies on this question found that antioxidant supplementation consistently attenuates exercise-induced oxidative stress, but any physiological benefit of this attenuation has not been consistently demonstrated, since most studies report no effect on exercise-induced muscle damage or performance. More strikingly, a growing body of evidence indicates that antioxidant supplementation can have detrimental effects on the health and performance benefits of exercise training itself, interfering with ROS-mediated processes such as vasodilation and insulin signaling. In other words, the supplement that was supposed to protect the athlete may instead blunt the very adaptations training is meant to produce.

This pattern recurs across specific micronutrients. A focused review of Vitamin E and Vitamin C supplementation in exercising populations concluded that increased oxidative stress during exercise produces free radicals that can cause muscle damage and fatigue, but these same free radicals act as signaling molecules that enhance protection against future physical stress, and current evidence suggests antioxidant supplementation may impair these adaptations. The authors went further, noting that because antioxidant supplements such as Vitamin E and C tend to block anabolic signaling pathways, they may impair adaptations to resistance training, and special caution should be exercised with their use. Vitamin C in isolation tells a similar story: of fourteen randomized controlled trials reviewed, three showed positive outcomes for decreased markers of muscle damage, but the remaining eleven showed either neutral or negative effects of high-dose Vitamin C supplementation on muscle damage, physical performance, perceived soreness, or training adaptations, leading the authors to conclude that long-term high-dosage Vitamin C supplementation is not recommended, and athletes should instead obtain antioxidants through a nutrient-rich diet.

A broader review of micronutrients in sport reached a parallel verdict, observing that the balance of the literature suggests micronutrient supplementation in well-nourished athletes does not enhance physical performance, and excessive intake of dietary supplements may impair the body's physiological responses to exercise that support adaptation to training stress. This does not mean antioxidant supplementation is never warranted. In some cases-such as a diagnosed deficiency, compromised energy intake, or training and competing at altitude-supplementation may be appropriate, though it should be prescribed by a medical professional rather than self-administered. The exception proves the rule: supplementation makes sense when correcting a genuine deficit, not as a blanket performance strategy layered onto an already adequate diet.

There is a partial counterpoint worth acknowledging. Whole-food sources of polyphenolic antioxidants appear to behave differently than isolated high-dose vitamins. Tart cherry juice, for instance, has been studied specifically in athletic recovery contexts, and a review of this literature found that tart cherry's antioxidant and anti-inflammatory polyphenols lessen pain and accelerate strength recovery after exercise while decreasing blood markers

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of inflammation and oxidative stress, across both strength and endurance modalities. Critically, the same review distinguished training phases: tart cherry supplementation may not be optimal during the adaptation or build phase of training, but during periods where excessive inflammatory or oxidative stress from intense competition threatens to delay return to peak form, and recovery rather than adaptation is the priority, it may be beneficial. This periodization-sensitive framing-protect adaptation during training, support recovery during competition-offers a more nuanced model than blanket antioxidant use.

The practical implication for athletes, coaches, and sports dietitians is straightforward, if counterintuitive to popular supplement culture: chronic, high-dose antioxidant supplementation during a training block is more likely to blunt adaptation than to enhance it. The oxidative stress generated by training is not a problem to be eliminated; it is, within physiological limits, the mechanism by which the body becomes fitter. Athletes are generally better served by a varied, micronutrient-rich diet, reserving isolated supplementation for diagnosed deficiencies, altitude exposure, or short-term recovery windows around competition rather than as a year-round training companion.

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