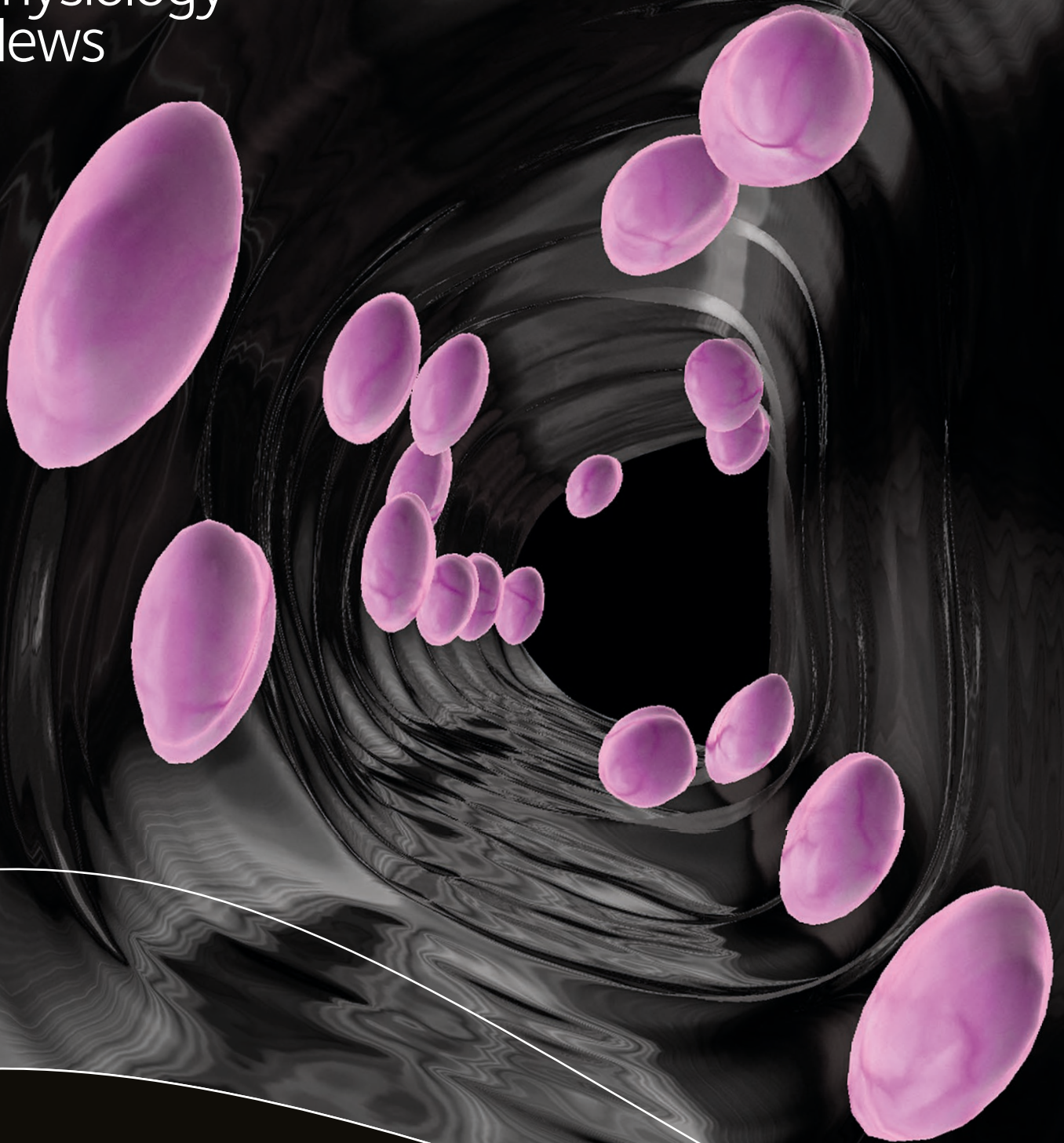


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edition of *Physiology News*

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Nutritional supplements to reduce muscle damage and enhance athlete recovery

What is the physiological evidence?

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In the lead-up to the Olympics this summer, athletes will be looking for strategies to maximise their performance. One popular strategy is the use of dietary supplements. Many reasons for the use of dietary supplements have been reported in the scientific literature, including in the support of athlete recovery (Maughan *et al.*, 2018). Some of the most common supplements used by athletes are protein and creatine, but what about other nutrients? Can vitamin D boost recovery times? Can beetroot juice attenuate muscular soreness? In this article, we examine the benefits of vitamin D, tart cherry juice, and beetroot juice.

An important aspect of athlete recovery is exercise-induced muscle damage (EIMD), which can be triggered by various modes of exercise, including resistance training, prolonged running, and intermittent high intensity exercise (Owens *et al.*, 2019). Mechanistically, EIMD results in muscle structure damage, muscle soreness, decreased range of motion, and impaired force-producing capacity. EIMD is known to occur in two phases. The first phase involves initial structural damage resulting from mechanical and metabolic stress during exercise (Owens *et al.*, 2019); and the second phase involves inflammatory responses to damaged tissue. This occurs in the hours/days post-exercise, and is considered an important part of the muscle repair process (Harty *et al.*, 2019). The temporary loss of muscle functional capacity in the second phase and the increase in muscle soreness can be detrimental to athlete recovery and can impede next-day training sessions and/or performance. Therefore, nutritional interventions are frequently used to accelerate muscle recovery and ameliorate muscle soreness (Owens *et al.*, 2019).

Vitamin D

Vitamin D signals via vitamin D receptors (VDRs) to maintain optimal bone health, regulate muscle growth, and support immune function. Vitamin D comes in two forms: ergocalciferol (vitamin D₂) and cholecalciferol (vitamin D₃). Vitamin D₂ is obtained through diet (e.g. animal sources, fortified foods); and vitamin D₃ is synthesised in the skin via a reaction triggered by sunlight, although vitamin D₃ can also be introduced through animal sources and fortified foods in the diet. Staggeringly, up to 62% of athletes (depending on the time of year and geographic location) could have blood vitamin D levels of < 50 nmol·L⁻¹ (Maughan *et al.*, 2018). As this is considered suboptimal for most people, and considering the vital roles played by vitamin D, many governments recommend vitamin D supplementation particularly throughout the autumn and winter months.

Despite this recommendation, it is estimated that approximately only 7% of athletes use vitamin D as a performance supplement



(Harty *et al.*, 2019). There is some evidence that a high daily intake of vitamin D (up to four times the recommended guidelines of $1000 \text{ IU}\cdot\text{d}^{-1}$) may have a positive impact on athletic recovery. This is possibly due to the role of VDRs in activating the expression of genes that influence muscle growth, particularly in fast-twitch fibres. These effects on recovery, however, are likely dependent upon two factors: the type of vitamin D and baseline levels.

Vitamin D_3 supplementation has been shown to reduce circulating fatigue-related biomarkers (e.g. alanine and aspartate aminotransferases) after isokinetic force when compared with a placebo (Barker *et al.*, 2013). The effects of vitamin D_3 were both immediate (i.e. 1 hr post-exercise) and delayed (i.e. 24, 48, 72, and 168 hours post-exercise). However, these indicators of improvements in athletic recovery either decrease or disappear when vitamin D_2 is supplemented. This is likely because as vitamin D_2 levels increase with supplementation, it negatively impacts vitamin D_3 and therefore the total bioactive vitamin D levels. Vitamin D supplementation has been shown to benefit recovery when baseline concentrations are $< 50 \text{ nmol}\cdot\text{L}^{-1}$ (Maughan *et al.*, 2018), with adequate concentrations in athletes considered to be

$> 50 \text{ nmol}\cdot\text{L}^{-1}$. This is likely because of the role vitamin D plays in the regulation of calcium and phosphate transport, which directly affects muscle cell growth. It is worth noting, however, that this evidence is based on very few studies, hence the results are suggestive rather than conclusive.

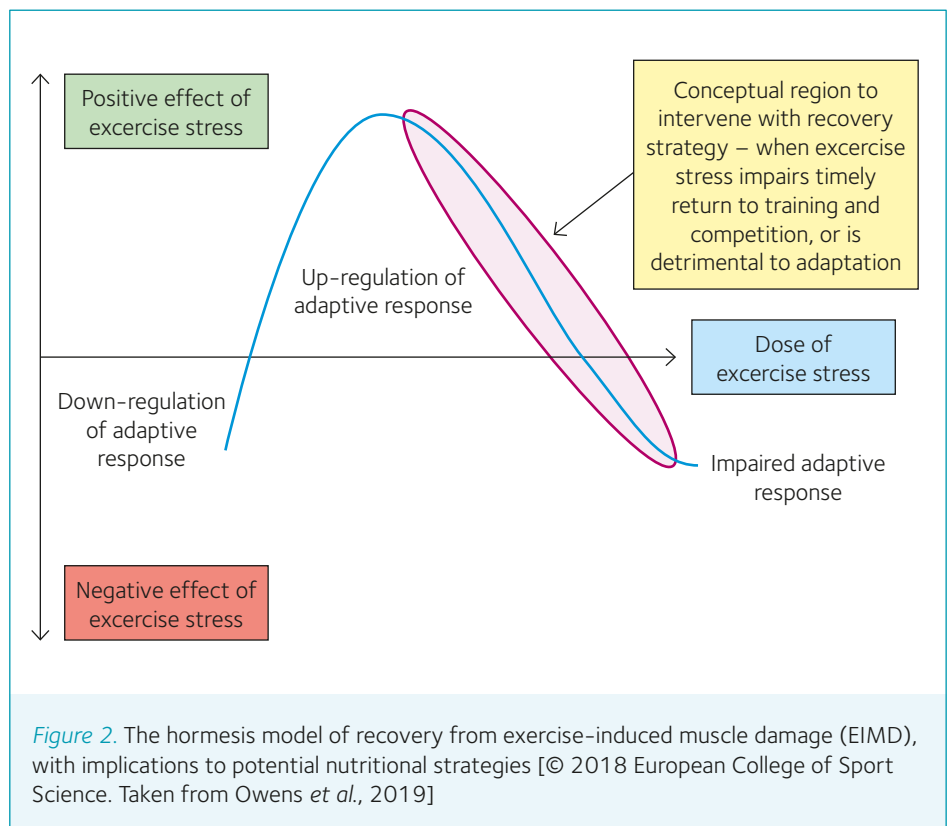
Tart cherry juice

Tart cherry juice is rich in anthocyanins, a type of flavonoid pigment possessing antioxidant and anti-inflammatory properties. This is important because although an inflammatory response is needed for muscle repair and growth, prolonging the response can lead to EIMD including soreness and reduced muscle function (Owens *et al.*, 2019). The antioxidant and anti-inflammatory effects of tart cherry juice can dampen this inflammation and reduce EIMD, meaning athletes can compete and train more frequently (Harty *et al.*, 2019). The supplementation of tart cherry juice appears to effectively reduce the effects of EIMD and oxidative stress, and therefore allows athletes to recover, train, and compete more frequently. One study found that after 3 days of supplementation with 340 mL of tart cherry juice both in the morning and evening, EIMD-related symptoms (e.g. strength loss, pain) were significantly decreased in healthy college-aged male

athletes, while force production increased by approximately 19% compared with placebo (Connolly *et al.*, 2006). Furthermore, short-term consumption of cherry skin powder for 7 days in resistance-trained male athletes reduced the perceived soreness by an average of 44% during the 48 hours after exercise (Levers *et al.*, 2015).

The study authors also reported increased recovery of serum total protein by 6%, which also aids in the muscle recovery process. Chronic consumption of tart cherry juice (i.e. approximately 60 mL of juice concentrate or 500–750 mL of juice or 480 g of cherry skin powder per day for 7–8 days) appears to ameliorate declines in muscle function (Brown *et al.*, 2019), reduce biomarkers of EIMD, and decrease perceptions of pain in both male and female athletes and non-athletes when compared with placebo controls (Harty *et al.*, 2019). Therefore, this strategy could have multiple benefits, particularly for those individuals who train frequently (both endurance and strength sports) and/or for those who have multiple events in a short period of time. It's been stated that the mechanism behind tart cherry's health benefits is due to the bioactive compounds, including various polyphenolic compounds that act as high level antioxidants (Harty *et al.*, 2019).

“Although the promise of nutritional supplements may offer a beneficial strategy to support training recovery, and ultimately performance, our recommendations would be to focus on a wholefood-first approach.”



Beetroot juice

Beetroot juice may also reduce the effects of EIMD. This is possibly because of nitrates in beetroot and betalains, a type of pigment, again with antioxidant and anti-inflammatory properties similar to tart cherry juice with similar positive health effects and mechanisms (Clifford *et al.*, 2016). Additionally, following ingestion, nitrate is converted to nitrite in the blood (Jones, 2014). In conditions of low oxygen availability, nitrite can be converted into nitric oxide, which is known to play several important physiological roles. These include regulation of blood pressure, enhancement of muscle efficiency, lowering the oxygen cost of submaximal exercise, and enhancing exercise tolerance and performance (Clifford *et al.*, 2016).

The consumption of either high (1.75 L) or low (0.875 L) doses of beetroot juice was found to significantly increase recovery of repeated performance in countermovement jumps over 48 and 72 hours following exercise in recreationally active males (Clifford *et al.*, 2016). On average, the high-dose group maintained performance up to 91.7% at 48 hours post exercise and 93.4% 72 hours post exercise, corresponding to a 16.4% and 7.3% improvement in recovery when compared with isocaloric placebo. The low-dose group saw a similar improvement, which was not significantly different when compared with the high-dose group. Additionally, it has been demonstrated that beetroot concentrate improved running speed/pace over a 10 km course by 2% in both male and female competitive triathletes

when administered at 100 mg·d⁻¹ for 7 days (Montenegro *et al.*, 2017) whilst simultaneously improving muscle oxygenation and mitochondrial efficiency (Jones, 2014). These aided in recovery and performance, and reduced the degree of EIMD outcomes, such as muscle soreness, reduced range of motion and impaired muscle force production.

If some is good then more must be better?

Some athletes and recreational exercisers assume that if a small dose of a supplement yields benefits then taking more must be even better. However, there is little evidence to support this assumption, and, for some supplements, increasing the dose can increase the risk of toxicity. Regarding vitamin D supplementation, for example, there is no evidence that supplementing more than 4000 IU·d⁻¹ has any added benefits to athletic recovery (Owens *et al.*, 2019). Similarly, for both tart cherry and beetroot juice, a recommended dose of approximately 60 mL of concentrate (~500–800 mL of juice or 480 g of cherry skin powder) throughout the day for at least 3 days appears to be advantageous to an athlete’s performance and recovery (Brown *et al.*, 2019). Although, juice doses of 1.75 L·d⁻¹ have been shown to still have positive effects without any signs of toxicity, suggesting that a higher dose is possible (Harty *et al.*, 2019; Clifford *et al.*, 2016). It is worth noting that, although nitrate is not generally considered toxic, there is the possibility of toxicity with the use of nitrite salts owing to haemoglobin oxidation (Jones *et al.*, 2014). As such, it is recommended that athletes use natural

vegetable products and trial their use prior to competition to optimise supplementation strategies and avoid any potential negative effects.

Discount the placebo effect at your peril!

This article has discussed the potential benefits of novel supplements to improve athletic recovery. And yet, there is one effect that has received more attention than all of the others put together: the placebo. There is extensive evidence that placebos are effective, with people who take them exhibiting significant improvements in athletic performance and in post-exercise recovery (Clifford *et al.*, 2016; Brown *et al.*, 2019). Thus, it would seem that if an athlete believes that a supplement will help in athletic recovery, it is likely that the placebo effect will make it so. Nevertheless, studies have shown that nutritional supplements, including vitamin D, tart cherry juice, and beetroot juice can improve the recovery of muscle function by alleviating markers of EIMD compared with a placebo (Harty *et al.*, 2019). Scientific research undoubtedly presents evidence of the effects of nutritional supplementation providing a genuine physiological effect, which reduces EIMD and enhances performance and recovery. However, the power of the placebo effect also unquestionably affects these outcomes.

Other nutritional supplements

We should acknowledge that although vitamin D, tart cherry and beetroot juice have been discussed in this article, there are other nutritional supplements and food items that have been demonstrated to reduce EIMD and enhance the recovery of athletes. These include creatine monohydrate, omega-3 fatty acids, protein (i.e. whey), watermelon juice, and pomegranate juice (Harty *et al.*, 2019). Additionally, there are a plethora of other nutrients and/or food items that mechanistically could offer therapeutic potential, and further research is clearly warranted in this domain; for example, bromelain (found in pineapple), ginger, curcumin, β -hydroxy- β -methylbutyrate (HMB), quercetin, cocoa, and caffeine. However, it should be highlighted that a natural, wholefood-first approach in athletes should be endorsed as a primary starting point. Nutritional supplements should only be used to complement a phytonutrient, protein-rich diet to support exercise recovery where scientific evidence, consideration of product safety, and pertinent application exist.

Practical applications

Strategies in combatting EIMD via nutrient supplementation must consider the chronic application of many of these as they may impair long-term adaptations (Harty *et*

al., 2019) given that oxidative stress and inflammation play an important role in many skeletal muscle adaptations including growth, strength and hypertrophy (Owens *et al.*, 2019). However, maximising recovery capacities at the cost of long-term training adaptations may be advantageous in athletes who need to recover quickly between training sessions and events. It is also noteworthy that the chronic and persistent use of nutritional supplements to alleviate EIMD by attenuating the inflammatory response may subsequently impair long-term muscle adaptations. Therefore, a periodised approach to supplementation may yield the greatest benefits to the athlete along with considering the trade-off between muscle recovery and adaptation (Owens *et al.*, 2019). Considering this, it is recommended that athletes work with a nutrition/medical professional and trial strategies before beginning any intervention, particularly for elite athletes and during competitions.

Although the promise of nutritional supplements may offer a beneficial strategy to support training recovery, and ultimately performance, our recommendations would be to focus on a wholefood-first approach (e.g. appropriate energy intake, sufficient protein quantity/quality, and a phytonutrient/polyphenol-rich diet) before considering supplementation. Additionally, with supplementation, the use of approved Informed Sport products should be considered to minimise risks of falsely advertised batch products. Finally, it may also be advantageous to implement practical treatment recovery (e.g. sports massage, ice bathing, stretching, foam-rolling etc) that can be used alongside nutritional strategies to maximise recovery and reduce the effects of EIMD. However, it's important to note that the research into applications of these supplementation are still in its infancy and longer-term studies are warranted.

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