



ERGOGENIC AIDS THAT WORK



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Ergogenic Aids

Mechanism of Action

Ergogenic Benefit

Recommended Use & Potential Side Effects

Indirect Performance Enhancing Supplements

adjective, ər-gə- ' je-nik

“enhancing physical performance”

-Merriam-Webster

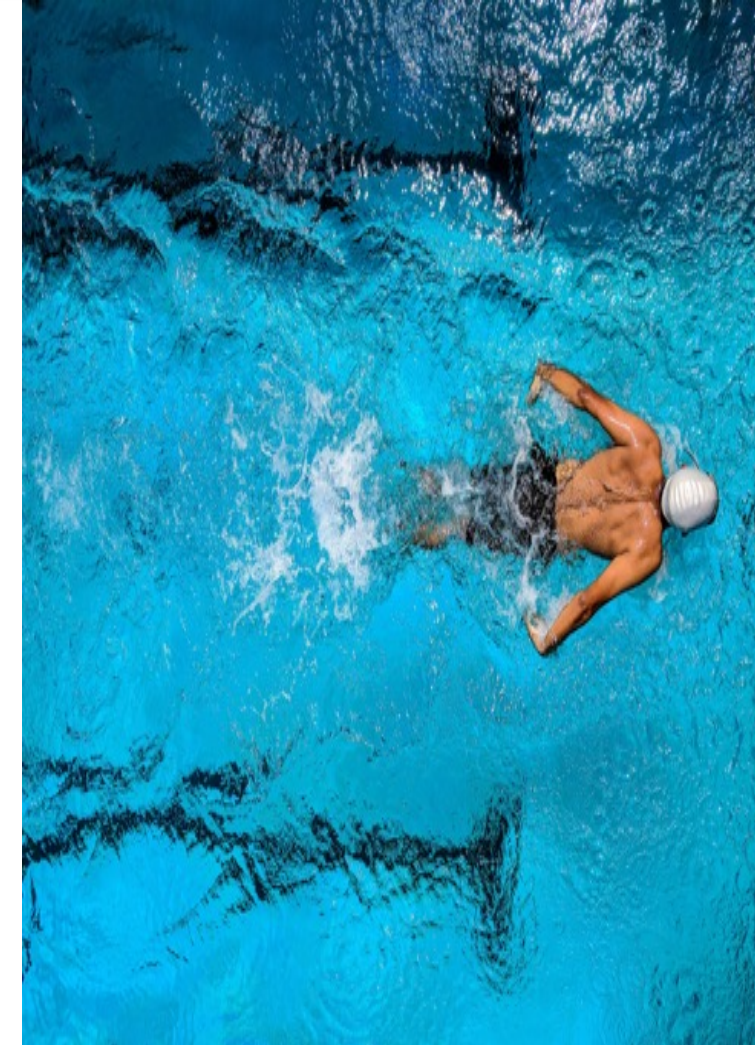
For purposes of this presentation, only those dietary supplements recognized by the International Olympic Committee (IOC) will be included. The IOC, being a regulating body, is a trusted resource in the evaluation of nutritional supplements for individuals and athletes.



In review of the literature, a team of scientists working with International Olympic Committee (IOC) has identified a short list of supplements that do show benefits on athletic performance:

Caffeine
Creatine
Beta-Alanine
Nitrate
Sodium Bicarbonate

The IOC is a regulating body and a trusted resource in the evaluation of nutritional supplements for individuals and athletes.





CAFFEINE

- Caffeine (**1,3,7** – trimethylxanthine) is a natural alkaloid
- Present in the leaves, fruits, and seeds of a variety of plants such as coffee and tea
- Most well-studied and widely used supplement
- Removed from the restricted list of the World Anti-Doping Agency in 2004



Pioneering work by Dr. Dave Costill & colleagues at Ball State University, late 1970's



Time to Exhaustion
(80% VO_2 max)



5 mg/kg
(~330 mg)

96
min



0 mg/kg

75
min



Work Completed
(over 2 h)

250 mg pre-cycle
250 mg x 7 during cycle

20% increase in
work completed



SSE#203



ERGOGENIC BENEFIT

Caffeine enhances aerobic endurance, muscle endurance, power, jumping, speed and overall awareness.

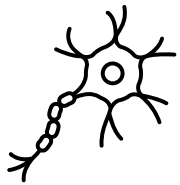
- Improved reaction time, concentration and self-perceived energy levels
- Enhanced endurance performance
- Enhanced glycogen resynthesis
- Improved performance in repeated high-intensity exercise bouts (i.e. team sports)
- Little to no effect on strength-based activities
- Velocity is enhanced and velocity loss attenuated over consecutive repetitions



MECHANISM(S) OF ACTION



Initial hypothesis during for improved endurance performance: metabolic
-Increased lipolysis, sparing muscle glycogen



Upon further research, it appears caffeine impacts the CNS and PNS by acting as an adenosine receptor antagonist

-Increased central drive in the CNS, decreased perception of effort and pain in the PNS



Following ingestion, appears in blood stream within **15 to 45 minutes**, with peak levels appearing around **1 hour**

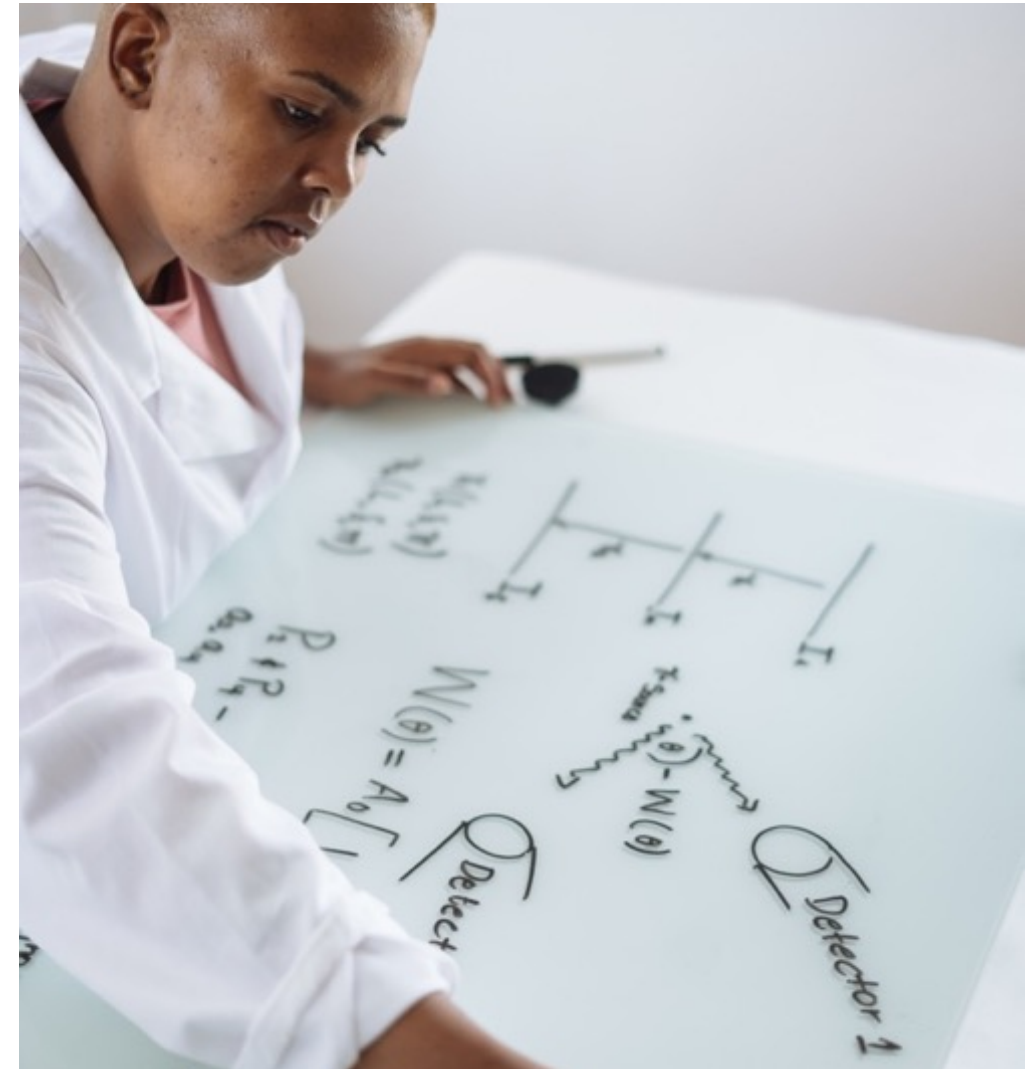
GENETICS & CAFFEINE

Some individuals do not experience performance benefits associated with caffeine ingestion

Recent research has emerged examining polymorphisms of certain genes

- CYP1A2
- ADORA2A

Further research is necessary, but clear that some individuals do not respond to caffeine ingestion



RECOMMENDED USE

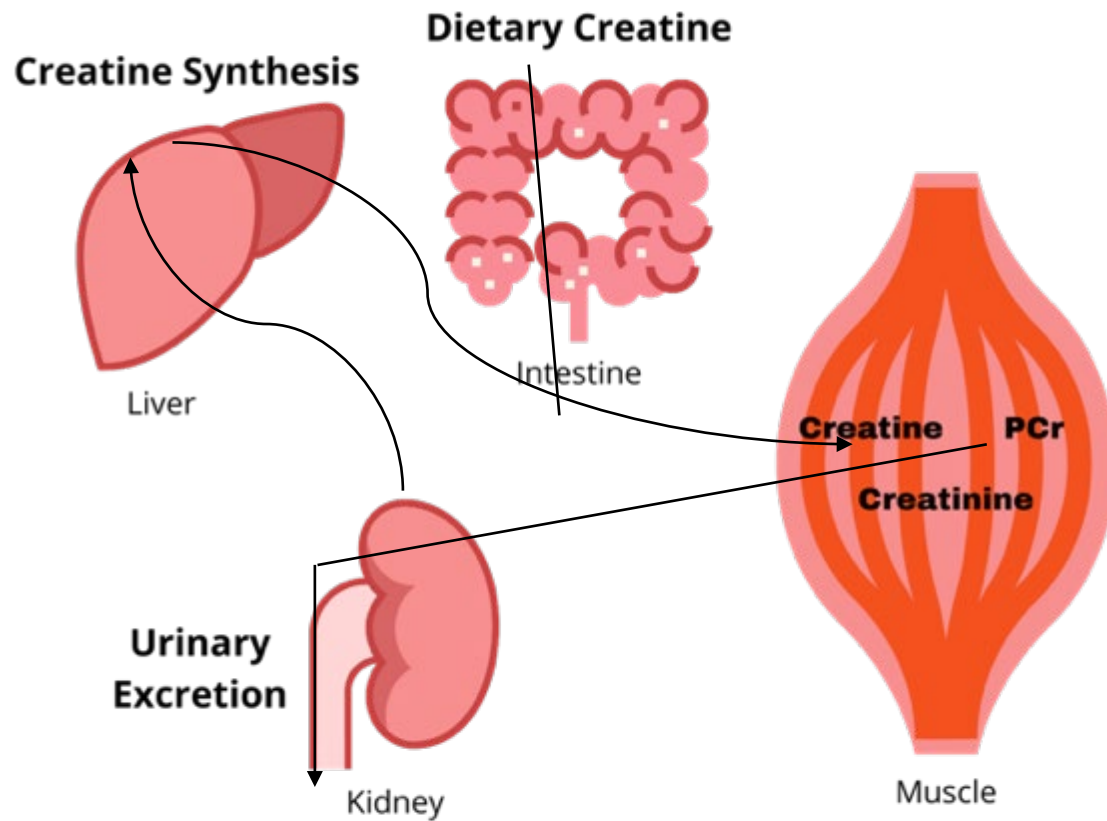
- Moderate to high doses (5-9 mg/kg) improve performance but are associated with increased heart rate, lactate, GI upset, nervousness, mental confusion, insomnia
- **Low doses of ~200 mg or ~1.5 to 3 mg/kg body mass are effective and should be used initially**
- Consumption can take place before, during and late into exercise
- Coffee and other caffeinated beverages, capsule/tablet, gels, gums, bars and dissolvable mouth strips are all effective for delivery
- The ergogenic effects of caffeine are generally independent of habitual caffeine use, training status, dietary intake, gender, hydration status and exercise modality, but results in the heat are less clear
- Caffeine is not a diuretic during exercise

Consideration: IOC and NCAA have limits on caffeine excreted in urine



CREATINE

CREATINE



- Creatine is synthesized in the kidney, liver, pancreas, and, to a lesser extent, the brain
- Synthesis is from the amino acids glycine, arginine, and methionine.
- The total body creatine pool includes creatine and phosphocreatine (PCr)
- Skeletal muscle is the primary site of storage accounting for up to **90%** of total body pool
- Total body creatine pool can be increased by ingestion of foods high in creatine (meat and fish) or nutritional supplementation

MECHANISM OF ACTION IN MUSCLE



PCr is an important energy source for high intensity, short duration muscle contraction

Creatine is essential for the regeneration of PCr

The creatine kinase (CK) phosphocreatine (PCr) system serves as an energy buffer in cells with high and fluctuating energy requirements

ERGOGENIC EFFECTS

Short-term benefits following 5-7 day loading include increased

- **Power production**
- **Sprint performance**
- **Work performed (i.e. multiple sets of maximal effort)**

Chronic training with elevated creatine levels

- **Increases lean mass gains**
- **Improves strength**
- **Improves power**

Less common improvements noted in endurance performance:

- **Reduced lactate at same relative workload**
- **Decreased oxygen cost**



Performance	Time/ Nature of Activity	Potential Benefit	Comments	Relevant Research
High intensity exercise - Laboratory tests	< 30 s	Increased peak/ mean power, decreased fatigue	Many supportive studies; more effective over repeated bouts of exercise	(reviewed in Branch, 2003; Gualano et al., 2012)
High intensity exercise - Field tests	< 30 s	Increased speed/ decreased time to complete a fixed distance	Supportive studies, fewer studies overall, theoretically the increase in body mass may reduce ergogenic effect in weight- bearing sports (e.g., running), but not known	
Swimming		Increased power/ decreased time to complete a fixed distance	Supportive studies for improved performance over repeated sprint intervals; probably not effective in single sprints	(reviewed in Hopwood et al., 2006)
Medium duration tasks	30 s to 5 min	Increased power output, speed / decreased time to complete a fixed distance	Some studies show enhanced performance, possibly due to increased muscle glycogen subsequent to creatine supplementation	(reviewed in Branch, 2003; Gualano et al., 2012)
Sprinting within or after endurance exercise		Increased power output, speed; decreased fatigue, time to complete a fixed distance	Supportive studies, but fewer studies overall	(Engelhardt et al., 1998; Vandebuerie et al., 1998; Tomcik et al., 2018)
Endurance exercise	> 5 min	Decreased oxygen cost of exercise	Most studies show no improvement in endurance performance	(Nelson et al., 2001; van Loon et al., 2003)
Strength and conditioning workouts	Intermittent	Spontaneous increase in total lifting volume, increased number of repetitions at a given weight, increased strength, increased lean body mass	Many supportive studies	(reviewed in Rawson & Volek 2003; Lanhers et al., 2017)

Table 1. Effects of Creatine Monohydrate Supplementation on Exercise Performance

RECOMMENDED USE

Loading phase

5 g/d for 4 weeks **OR** 20 g/d for 5 days

Maintenance

5 g/d

To cycle or not to cycle?

Cycling is not recommended

Creatine supplementation attenuates endogenous production

Consideration: Consuming carbohydrate with creatine enhances uptake

HOW DO YOU LIKE YOUR MEAT?

- **3** oz of raw beef equals approximately **0.4** g of creatine
- **3** to **6** g per **2.5** lbs of raw meat (estimated)
- Cooking affects creatine in meat by reducing total content
- Consideration: Athletes or individuals attempting to lose or maintain weight should consider the additional calories associated with consumption of large amounts of meat or fish for creatine



CREATINE SUPPLEMENTS

- Creatine monohydrate, most common form on the market, in solution increases whole body creatine to a greater extent than meat
- Other forms (ethyl ester, etc.) have not been found to increase muscle creatine to a greater extent and in some cases have been reported to result in less muscle creatine



POTENTIAL SIDE EFFECTS

After several decades of research, there is no persuasive evidence suggesting that oral creatine supplementation causes muscle cramps or adversely affects renal function or thermoregulation

The only potential side effect is weight gain



Potential Concern	Evidence of Reduced Function	Evidence of Improved Function	Evidence of No Detrimental Effect	Relevant Reviews
Renal stress	Case studies, confounded by drugs/medication, prior disease, other supplements	No trials show improved renal function	Multiple trials (> 20) using various methods, show no effect on renal function	(Gualano et al., 2012)
Muscle dysfunction	Case studies of exertional rhabdomyolysis, confounded by unaccustomed/ extreme exercise, drugs/medication, dehydration, traumatic injury, other supplements	Several trials show decreased muscle cramps, tightness, strains and total injuries in habitual creatine users. Several studies show decreased post-exercise inflammation, increased strength recovery, decreased delayed onset muscle soreness (DOMS)	Several trials show no evidence of improved or reduced muscle function	(Rawson et al., 2017)
Thermoregulatory strain	None	Some trials show decreased exercise body temperature	Several trials show no evidence of improved or reduced thermoregulatory function	(Lopez et al., 2009)
Other organ strain	None	None	Several trials show no change in markers of cardiac or liver function	

Table 3. Potential Safety Concerns with Creatine Monohydrate Supplementation

Like caffeine, some individuals will not respond to supplemental creatine ingestion

Why?

- Individuals with a greater proportion of type II muscle fibers are more likely to have higher concentrations of creatine in muscle
- Unfortunately, all tests to determine muscle creatine content are invasive and/or expensive
- Most individuals are likely to benefit from supplementation



BETA-ALANINE

BETA - ALANINE

- Endogenously produced in liver
- Total body beta-alanine can be increased by ingesting meat, including poultry, or through supplementation
- Rate limiting pre-cursor to carnosine (beta-alanine alone has little to no ergogenic benefit)

MECHANISM OF ACTION

- Beta-alanine is a pre-cursor to carnosine
- Carnosine has numerous physiological functions and is formed by the amino acids L-histidine and beta-alanine
- The ergogenic benefits are due to carnosine's intracellular proton buffering capacity
- Ingestion of carnosine does not result in increased muscle concentration due to lack of a specific enzyme in the muscle which results in carnosine being metabolized prior to reaching the muscle
- However, beta-alanine allows carnosine to be increased in the muscle



ERGOGENIC BENEFITS

- Improved exercise capacity in high-intensity events lasting 60 to 240s
- Allows for greater training volume in short event (i.e. lifting weight, sprinting)
- May benefit, though modest, in longer events (> 4 min) up to 10 minutes
- Attenuates neuromuscular fatigue



RECOMMENDATIONS

Recommended Use

- Chronic loading of 4 to 6 g/d (~65 mg/kg body mass) divided in doses of 2 or less for minimum of 2 weeks produces benefit
- Greater benefit after 4 weeks
- Single bolus not recommended due to acute paraesthesia (i.e. skin tingling) and no performance benefit

Potential Side Effects

- Paraesthesia (i.e. tingling) typically experienced in the face, neck, and back of hands
- Dose dependent with higher doses resulting in greater effect
- Time released formulations reduce paraesthesia
- No long-term (> 1 yr) safety data



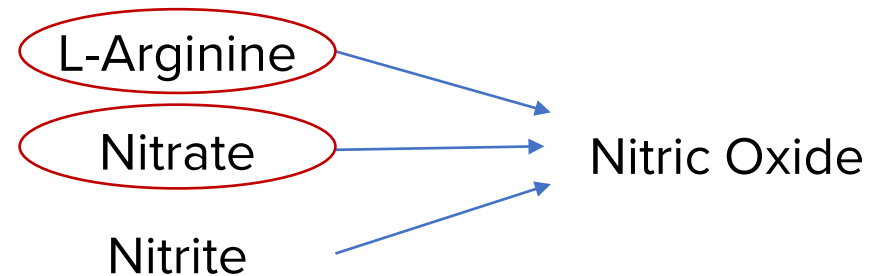
NITRATE

- Nitrate (NO_3^-) is a naturally occurring anion in the body involved in the biosynthesis of nitric oxide (NO) which has many physiological functions in the body
- Green leafy and root vegetables are rich in nitrate
- Ingestion of nitrate rich foods contributes to the formation of nitric oxide



MECHANISM OF ACTION

Nitric Oxide: regulation of blood flow, muscle contractility and mitochondrial respiration



ERGOGENIC BENEFITS

- Reduced oxygen cost of submaximal exercise
- Improved muscle efficiency
- Increase time to exhaustion during high-intensity continuous and intermittent exercise
- Unknown if nitrate is ergogenic for highly trained athletes



RECOMMENDATIONS

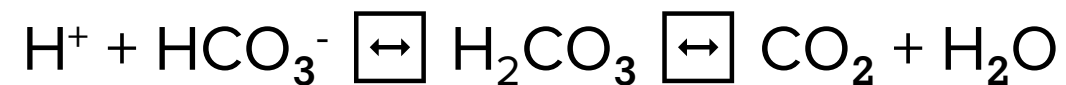
- 5-7 mmol nitrate (~0.1 mmol/kg body mass)
- Typically peaks within 2 to 3 hours and remains elevated for 6 to 8 hours
- Consume ~3 hours prior to competition
- A daily dose is required to keep NO elevated
- Adaptations to training are unclear
- No known side effects at recommended dose



SODIUM BICARBONATE

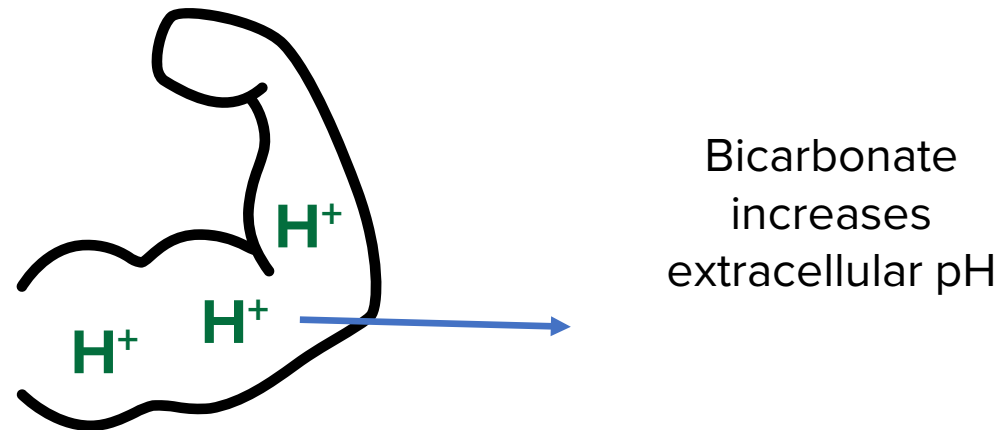
SODIUM BICARBONATE

- The study of alkalosis to enhance performance goes as far back as 1930
- Sodium bicarbonate (NaHCO_3) has been purported to be the most effective ergogenic aid
- Sodium bicarbonate increases the level of bicarbonate in the blood which is a natural buffer



MECHANISM OF ACTION

- Maintains pH between intracellular and extracellular space
- Maintenance of muscle function



ERGOGENIC BENEFIT

- Enhanced performance in exercise or event in which there is a reliance on anaerobic glycolysis
- Benefit for events between 30-120 seconds
- Recent review highlighted no difference in effect size in medium (2 to 10 minutes) and long (>10 minute) exercise
- Benefits realized in high intensity intermittent exercise (team sports)
- Evidence suggests more beneficial for untrained

RECOMMENDATIONS

Recommended Use

0.2 to 0.4 g/kg body mass
ingested 1-2 hours before
training or competition

Try it first during training!

Potential Side Effects

Gastrointestinal distress including...

- Pain
- Diarrhea
- Vomiting
- Gas
- Nausea



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INDIRECT PERFORMANCE ENHANCING

The IOC characterizes some supplements as “indirect performance enhancing” due to their effect on return to performance (injury recovery), soreness, or training capacity

In addition to performance enhancing benefits, creatine also play a vital role in recovery

- Reduced delayed onset muscle soreness
- Improved cognitive processing
- Enhanced recovery from mild traumatic brain injury (mTBI) (i.e. concussion)

Supplementation for recovery is the same as for performance

OMEGA - 3 FATTY ACIDS

- Components of cell membranes, important for cardiovascular and neurological health
- Docosahexaenoic Acid (DHA) and Eicosapentaenoic Acid (EPA)
- The body can produce DHA and EPA from ALA; however, that process is limited and inefficient
- Fatty fish are rich dietary sources
- Most individuals are deficient, and several studies have highlighted deficiency in college athletes



OMEGA - 3 FATTY ACIDS

Benefits may include....

- Enhanced muscle protein synthesis
- Improved cognitive processing
- Enhanced recovery from mTBI
- Enhanced recovery from exercise (may be due to anti-inflammatory properties of EPA)
- Recommended dose is 2 g/d; though optimal ratio is unknown. 2 g/d DHA is recommended for enhanced mTBI recovery



VITAMIN D

- Essential fat-soluble vitamin
- Obtained from exposure to sun
- Low vitamin D levels are often observed in athletes
- Measure status with a blood test
- Vitamin D is associated with numerous important biological actions relevant to the athlete including regulating bone health, immune function, cell cycle and skeletal muscle homeostasis
- RDA = 600 IU/day



GELATIN & VITAMIN C

- Collagen is the primary protein in connective tissue (tendons and ligaments)
- Gelatin is made from animal collagen and used in jellies and gummies to produce the gelatinous texture
- Increased collagen production has been observed following consumption of gelatin + vitamin C
- Additionally, decreased joint pain has been observed
- Recommended amounts: 15 g gelatin with 50 mg vitamin C

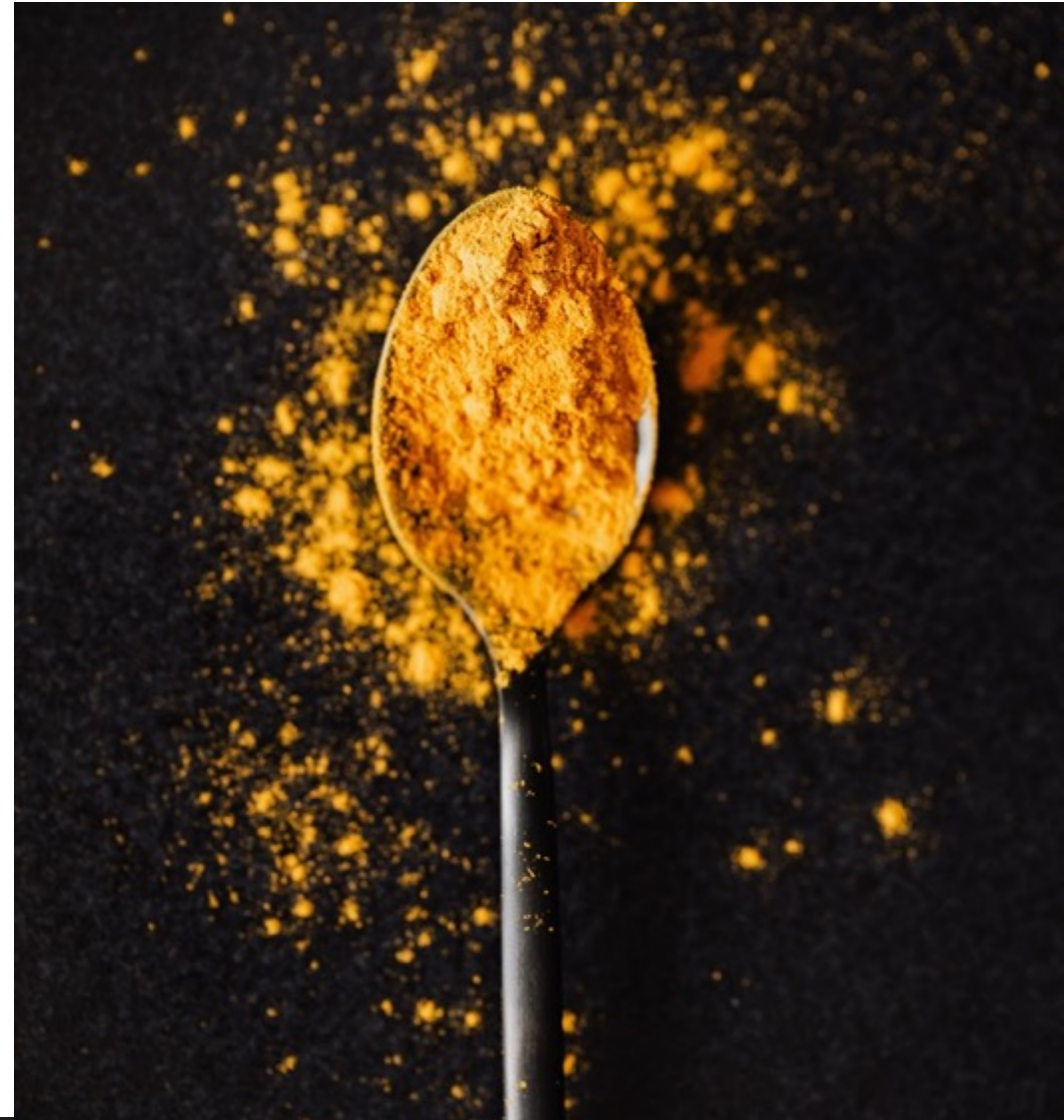


NON-DRUG ANTI-INFLAMMATORIES

Some foods have anti-inflammatory properties which may reduce the symptoms associated with muscle soreness and enhance recovery

- **Curcumin**, the bioactive ingredient in the spice turmeric, has anti-inflammatory properties
- **Tart cherries** also have bioactive ingredients purported to promote recovery

Recommended dose: 250-350 mL (30 mL concentrate) tart cherry juice twice daily



KEY TAKEAWAYS

- ✓ Caffeine, creatine, beta-alanine, nitrate, and sodium bicarbonate are direct performance enhancing supplements that may provide benefit if used appropriately and with the right type of exercise activity.
- ✓ Ensure the athlete has a sound nutritional base before adding supplements, even those with benefits
- ✓ No supplement should be tested on competition day and/or game day. Care should be taken to ensure an athlete does not experience any side effects and that the desired benefit is realized.
- ✓ Indirect performance enhancing supplements may provide additional support by enhancing those periods of recovery, allowing for better health and enhanced recovery.



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