Dietary Supplements

for Female Athletes

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Introduction

The prevalence of supplement use in athletes is high, ranging from 40 to 100% depending on the type of sport and competitive level. Supplement use is reported to be higher in female athletes compared to males. However, females tend to consume more vitamin and mineral based supplements, whereas males are more likely to use supplements associated with improving muscle mass (e.g., creatine and protein powder). In addition, supplement use is greater in elite athletes, compared to non-elite, as well as those competing in endurance-based sports (compared to other sports).

The information below will focus on ergogenic supplements (i.e., those intended to enhance performance) that may be beneficial to female athletes, and how they can be used safely. It is important to emphasize that a cost/benefit analysis should be completed by a qualified professional, in consultation with the athlete, before an athlete uses a supplement. The athlete's needs, preferences, and sport type should be considered, amongst other factors.

- 40-100% of athletes use supplements
- Supplement use higher in elite vs. non-elite
- Supplement use higher in females vs. males
- Females tend to use more vitamin and mineral based supplements

Safety and quality assurance

The supplement market continues to grow exponentially, with many supplements using exaggerated claims. The supplement industry is not universally regulated and, as supplements are used extensively within the athletic population, the possible contamination and/or adulteration of supplements with prohibited substances puts athletes at risk of breaking anti-doping legislations. The World Anti-Doping Association (WADA) openly states that athletes are responsible for anything that is found within their body, and supplement use should align with the WADA code of conduct. Therefore, appropriate steps must be taken to reduce the risk of an athlete producing a positive doping test result, and a cost/benefit analysis should be completed and guided by a qualified professional.

Quality assurance is also essential to ensure safe supplement use. There are several quality assurance programs available, for example NSF Certified for Sport. This third-party organization batch tests supplements provided by manufacturers and ensures that products do not contain unsafe levels of contaminants, or prohibited substances, and that the label matches what is in the product. Should an athlete wish to use a supplement, it is strongly recommended that they purchase it from a manufacturer that uses one of these quality assurance programs. However, while these programs provide considerable protection, they are not an absolute guarantee of supplement quality.

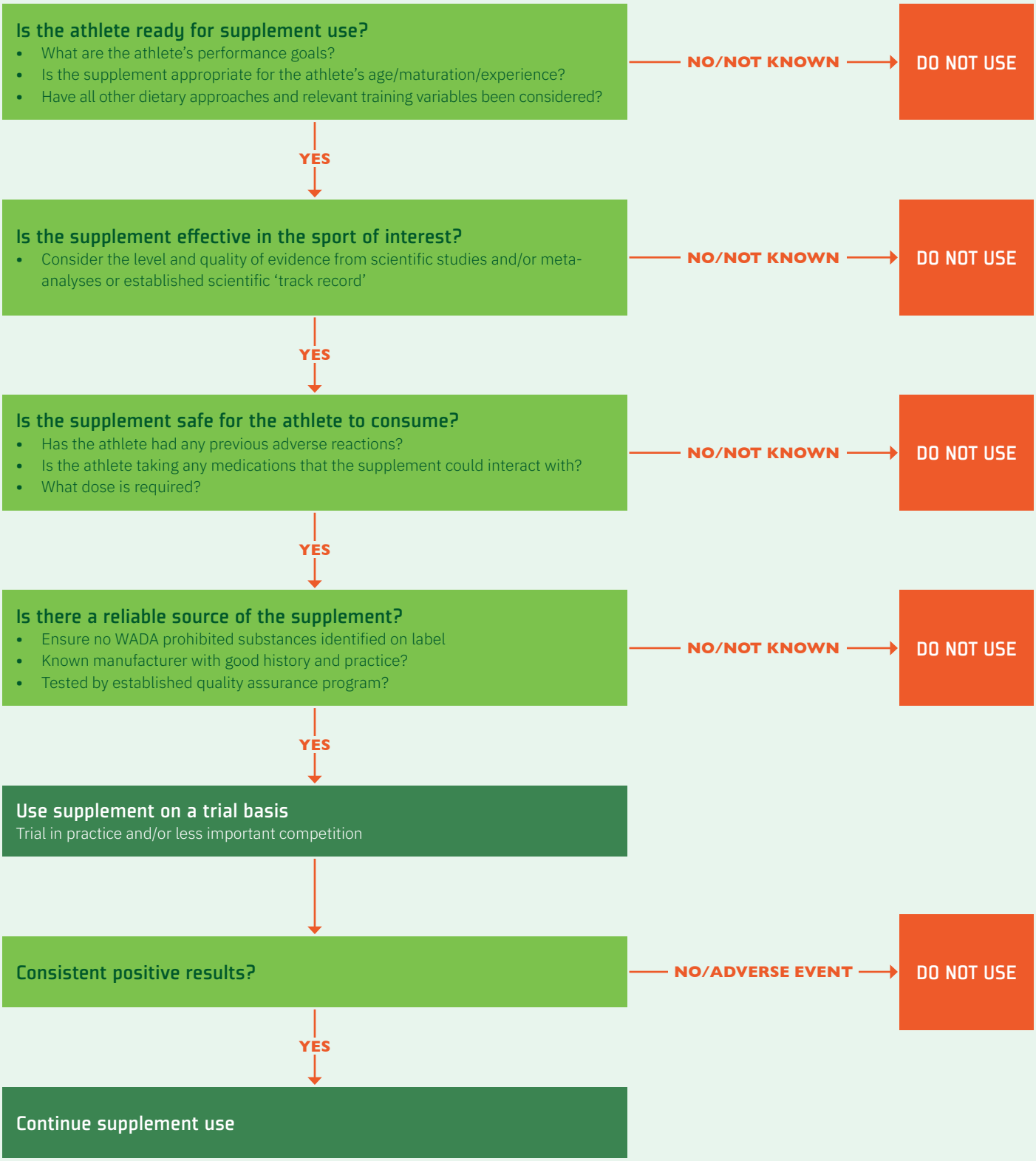
Athlete supplement safety

- Advice should be obtained from a qualified professional
- Supplement use should be in line with the WADA code
- Supplements should only be purchased from companies that use a quality assurance program
- Recommended doses should not be exceeded

Figure 1: Ensuring supplement safety with athletes

Supplement use decision tree

The flow chart below can be utilized to ensure the athlete makes an informed decision on consumption of an ergogenic supplement (i.e., a supplement aimed to enhance athletic performance).



Adapted from Maughan et al. (2018)

Creatine

Creatine is an amino acid mainly located in skeletal muscle (95%), with small amounts located in the brain. Creatine is produced endogenously in the liver and the brain, however it can also be consumed within the diet through foods like fish and red meat, or it can be supplemented (as creatine monohydrate).

Oral creatine monohydrate supplementation has been found to improve high-intensity exercise. This is by increasing skeletal muscle stores of free phosphocreatine, by as much as 20–40%, which can then be used to produce and maintain energy.

Supplemental creatine is primarily recommended for athletes who play sports that require quick bursts of power or strength (e.g., weightlifting), or sports that involve repeated high-intensity intermittent running (e.g., team sports).

Females have higher endogenous muscle creatine concentrations in comparison to males (relative to tissue mass). It has been suggested that individuals with high muscle creatine levels might have a smaller positive response to creatine supplementation. However, a meta-analysis found female participants to have greater relative improvements in performance variables from baseline compared to males when supplemented with creatine monohydrate. The data here is limited and of low quality, however it does suggest that daily supplementation of creatine monohydrate may be beneficial to female athletes.

In addition to increasing energy stores, other benefits of creatine supplementation include:

Increased muscle strength and power in response to training via possible increased gene expression and increased intracellular water, as well as enhanced recovery from muscle damaging exercise.

Improved bone health: preliminary research in older adults has found that the combination of creatine supplementation and resistance training can have positive effects on bone tissue by altering the bone remodeling process. It is possible that creatine supplementation may also benefit the bone health of athletes.

Enhanced cognitive function: there is also emerging evidence that creatine may benefit certain aspects of cognitive function, such as improved memory, and the ability to maintain cognitive function when the brain is stressed (e.g., sleep deprivation or mental fatigue). Thus, creatine supplementation might be a consideration for athletes to use strategically during certain phases of the season i.e., intense periods of competition.

Guidance

Two dosing protocols can be used for creatine supplementation:

1. ‘Loading phase’ of 4 x 5 grams/day for 5-7 days followed by a ‘maintenance dose’ of ~5 grams/day
2. Longer duration ‘maintenance dose’ of ~5 grams/day

If using in powder form, creatine can be taken within a meal or snack e.g., by adding the powder to oatmeal or a smoothie, or mixing the powder into a drink. If using in tablet form, it can be swallowed with a drink.

Consideration

The ‘loading phase’ is often associated with weight gain due to an increase in skeletal muscle water retention. Therefore, for athletes who may be more concerned with gaining weight, the second protocol may be more appropriate. It is worth noting that this response is individual and may potentially not be as evident in females compared to males.

Cycling creatine supplementation throughout a season

Athletes may wish to 'cycle' creatine supplementation throughout a season (Figure 2). This is because it takes weeks for body creatine stores to return to baseline levels once stopping supplementation. If they do this, then the athlete may wish to take creatine during specific stages of the season e.g., pre-season and during periods of competition. This figure shows an example of how the athlete could cycle creatine during their season. This can be adapted to fit the season of the sport that the athlete competes in. It should be noted that cycling creatine supplementation is not essential and is down to individual preference.

- Creatine supplementation
- No supplementation

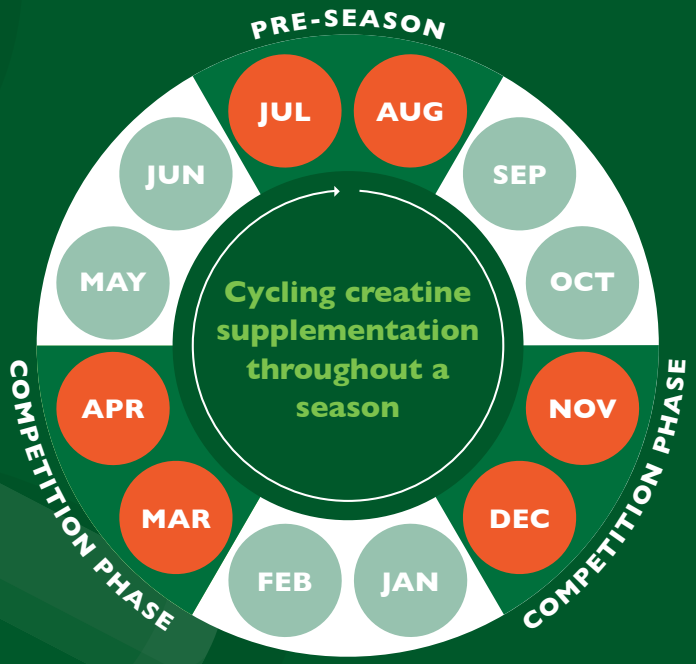


Figure 2: Cycling creatine supplementation

Protein powder

The macronutrient protein is an essential part of an athlete's diet. It is beneficial for building muscle mass, as well as recovering post-exercise.The majority of an athlete's protein intake should come from food sources however, it can sometimes be difficult to meet the elevated daily protein requirements for athletes, particularly when travelling or during periods of intense training or competition. Protein powder provides a convenient and simple way to increase daily protein intake, which can be used as an 'on-the-go' post-exercise snack and/or to supplement the diet, however it should not be used as a meal replacement alternative.

Whey, soy, casein, or plant-based protein blends containing all EAAs are are generally recommended for athletes because they are all considered 'complete' sources of protein (meaning that they contain all nine essential amino acids, including leucine which is an important amino acid for triggering muscle protein synthesis). For athletes following plant-based diets, soy or plant-based protein blends are suitable options.

Protein powder can be used in a variety of ways including:

- Mixed with water or milk
- Mixed into oatmeal or yogurt
- Blended into a smoothie
- Used as an ingredient in recipes e.g., pancakes, muffins, banana bread

Guidance

Servings of 20-40 grams (which usually equates to ~1 scoop) at a time

If the athlete is combining protein powder with other high protein foods e.g., milk or yogurt, then the amount of protein powder can be reduced so that the total meal/snack protein serving equates to 20-40 grams.

Whey Protein Isolate

25–30 g serving size suggestion

~2.5 g leucine per serving

Soy Protein Isolate

25–30 g serving size suggestion

~2.0 g leucine per serving

Casein Protein

25–30 g serving size suggestion

~2.0 g leucine per serving

Figure 3: Protein powder examples

Caffeine

Caffeine is widely used by athletes, with data reporting that ~75% of elite athletes use it as an ergogenic supplement. It is also one of the most studied supplements and has been shown to enhance athletic performance. Although the mechanisms by which caffeine exerts its performance enhancing effects are not fully known, it is thought that caffeine acts as an adenosine receptor antagonist. This results in increased central drive in the central nervous system, as well as decreased perceptions of effort and pain in the parasympathetic nervous system.

Potential benefits of caffeine supplementation

- Improves aerobic endurance exercise
- Reduces feelings of fatigue
- Improves cognitive function
- Improves repeated sprint performance

It is recommended that practitioners work with athletes to practice using caffeine in and around training sessions prior to using it on the day of a competition. This is because it allows time to practice with different doses to find out the optimal dose for the athlete (see below). In addition, it gives an understanding of any side effects that the athlete may experience, and if so, whether it may negatively impact performance. Finally, it allows time to understand the impact that it may have on the athlete's sleep, and therefore their recovery.

Guidance

3-6 mg of caffeine per kg of body mass, ~60 minutes pre-exercise (depending on the form of caffeine used)

The minimum dose of caffeine to induce performance enhancing effects is most likely ~2 mg of caffeine per kg of body mass, but it is likely to differ between individuals.

Calculating individual recommendations:

~60 minutes prior to exercise:

_____ body mass (kg) * 3 mg = _____ mg

_____ body mass (kg) * 6 mg = _____ mg

Consideration

Athletes must be aware of the adverse effects caused by consuming too much caffeine (e.g., headaches, anxiety, confusion, irritability, stomach discomfort, tachycardia) which can impact their performance.

Practical strategies

Athletes can slowly work up to the recommended amount of 3-6 mg/kg BM to establish the dose that they can best tolerate. To do this, an athlete can begin by ingesting a low amount of caffeine (e.g., ~1 mg/kg BM) before a training session, and then their responses can be evaluated (both physical and cognitive), as well as any adverse effects recorded. If this amount is tolerated, they can begin to gradually increase their caffeine dose in small increments until they find the most appropriate dose.

When deciding whether to use caffeine, athletes should take into account that caffeine will remain in the system for ~3-5 hours afterwards, which could have a negative impact on their sleep. If the exercise occasion is late in the day, athletes may want to consider adjusting their caffeine intake to an earlier time, or not using caffeine at all.

Sources of caffeine

There are various ways in which caffeine can be consumed (see below). It can be difficult to know the exact caffeine content of coffee because many factors can have an influence, including the brewing method, type of bean and quantity of coffee grounds used. Sports nutrition products containing caffeine (e.g., tablets, gums, or gels) will state the caffeine content on the packet, making it easier to know the exact amount being consumed. It is important to note that caffeine in caffeinated gum is absorbed more quickly in comparison to other forms, therefore it should be ingested ~5-15 min prior to exercise.


Coffee


Caffeine tablets


Caffeine gum


Sports gel containing caffeine

Sex differences

Females may have different metabolic responses to caffeine in comparison to men, and all individuals will respond differently. It is suggested that caffeine elimination is slower during the luteal phase of the menstrual cycle, and with oral contraceptive use. This accumulation of caffeine during high estrogen phases of the menstrual cycle may intensify the sympathetic effects of caffeine, as well as enhance pre-menstrual symptoms. Studies suggest that caffeine may decrease the perception of pain in females, which may allow for higher intensity and/or longer duration training sessions to be completed, resulting in greater physiological adaptations. However, more research is needed.

Beta-alanine

Beta-alanine (β-alanine) is a substrate of carnosine. Carnosine is an intracellular buffer which can reduce the development of muscle acidosis during intense exercise, through slowing the decline in muscle pH. As carnosine absorption by the intestine is not very effective, and β-alanine is rate limiting for carnosine synthesis, supplementation of β-alanine is required for increased plasma carnosine levels which can result in potential performance benefits.

Studies have shown that β-alanine can provide performance benefits during continuous (1-7 minutes) high-intensity exercise, where the main mechanism of energy production is predominantly glycolysis.

Examples of events where β-alanine may be beneficial are 200m swimming, 800m running, 4 km time-trial cycling, and 2000m rowing. However, most of these studies have investigated male athletes, with limited data available on female athletes. The data available in female athletes suggests that β-alanine may act as an ergogenic aid by delaying the onset of fatigue and lowering ratings of perceived exertion during exercise. Therefore, allowing exercise to be completed at a higher intensity, producing greater physiological adaptations and improving performance.

Consideration

Daily β-alanine doses are administered in multiple servings to minimize side effects, such as paresthesia (itching/tingling of the skin).

β-alanine (intracellular buffer) can be combined with an extracellular buffer (e.g., sodium bicarbonate) to provide an additive effect on performance. However, there is the possibility that gastrointestinal distress may occur.

Guidance

~3-6 g of β-alanine per day, administered as servings of ~0.8-1.6 g every 4 hours, for at least 4 weeks

This should be followed by a maintenance dose of 1.2 g per day.

Nitrate

Recent studies have shown that inorganic (dietary form) nitrate can enhance general health, as well as athletic performance. Nitrate can be obtained from dietary sources (Figure 4), however these food sources often require a large amount to be eaten before nitrate recommendations (6.5-13 mmol / 400-800 mg) are attained, therefore sports supplements (e.g., beetroot juice) are recommended as an alternative.

Guidance

6.5-13 mmol / 400-800 mg 2-4 hours before exercise

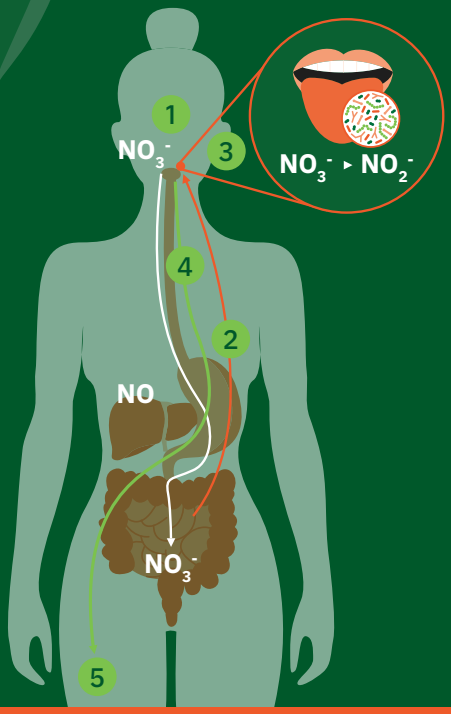
This is equivalent to 1-2 beetroot juice shots.

Figure 4: Foods rich in nitrate and their nitrate values (per 150g/5 oz serving)

How does nitrate supplementation work?

Nitrate supplementation works via second pass metabolism:

1. Nitrate (NO_3^-) is ingested
2. Nitrate (NO_3^-) passes into the blood stream and is delivered to the salivary glands to be secreted into the mouth
3. Using some species of bacteria in the oral microbiome, nitrate (NO3-) is reduced to nitrite (NO_2^-)
4. Nitrite (NO_2^-) is absorbed and converted into nitric oxide, which leads to the formation of other nitrogen intermediates that can then pass into the bloodstream and increase vasodilation
5. This has been found to improve muscle calcium handling and contractile function in skeletal muscle, which in turn can improve performance



Studies suggest nitrate supplementation improves:

- Endurance exercise performance
- All-out sprint exericse
- High-intensity intermittent exercise (e.g., team sports)

Mechanisms

Nitric oxide (NO) plays a role in other physiological processes including mitochondrial efficiency, neurotransmission, and muscle oxygen delivery. Nitrate supplementation might be beneficial for athletes because the enzymes that convert nitrite into NO are activated to a greater extent as acidosis and hypoxia develop in the blood and muscle, which occurs during intense exercise. Therefore, the NO pathway is enhanced during situations of acidosis and hypoxia (i.e., during intense exercise). Due to females having smaller blood vessels and a greater ability to reduce nitrate to NO compared to males, it is possible that nitrate supplementation may be more effective in females. In addition, there is some evidence to suggest that females have a better ability to generate NO through greater activation of the enzyme nitric oxide synthase, due to the stimulatory effect of estrogen on nitric oxide synthase. However, specific research on nitrate supplementation in females is very limited, with mixed results as to whether nitrate enhances performance.

Consideration

Athletes should refrain from using antibacterial mouthwash when supplementing with nitrate as it limits the metabolism of nitrate to nitrite by the microbiome.

Important

More research is needed with groups of recreationally active and elite female athletes, in varying menstrual states, with varied nitrate doses and durations, as well as different exercise modalities and durations.

Safe supplement use

Supplements that are offered across the sports nutrition industry continue to evolve. In an ever-changing landscape, it is important that athletes make educated choices to safeguard their health and well-being. Manufacturers can use promotional materials and non-substantiated claims that target female athletes, including 'helps you to lose weight', 'improves hormone balance', 'burns fat', 'increases energy', or 'helps you to stay healthy'. It is important to note that the scientific evidence to support these claims is often lacking, and ingesting these supplements might be harmful to health and performance.

Dietary supplementation should always be led by a qualified professional (e.g., a sports dietitian). It is encouraged to monitor the effectiveness of any supplement program via tracking changes in either health or performance indicators. Finally, athletes should always ingest supplements before, during or after training (depending on the supplementation protocol) to evaluate any potential negative side effects, prior to implementing supplement use around a competition.

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DIETARY SUPPLEMENTS

	Benefits	Sports	Guidance
Creatine	• Increases muscle strength and power • May benefit cognitive function when sleep deprived or mentally fatigued • May have positive effects on bone tissue	High intensity, intermittent exercise Strength and power sports	**Option 1:** **4x 5 g/day for 5-7 days, followed by ~5 g/day** **Option 2:** **~5 g/day** *Potential weight gain (due to skeletal muscle water retention) is highly individual and may potentially not be as evident in females compared to males*
Protein powder	• Convenient and simple way to increase protein intake • Supports performance and recovery needs	Appropriate for all sports	**Per serving: 20-40 g** **Whey, soy, casein, or plant-based protein blends containing all EAAs**
Caffeine	• Reduces feelings of fatigue • Improves endurance exercise and repeated sprint exercise • Improves cognitive function	Endurance exercise Repeated sprint exercise	**60 min pre-exercise:** **3-6 mg of caffeine per kg of body mass** **Be aware of adverse effects of consuming too much caffeine**
Beta-alanine	• Reduces development of muscle acidosis • Delays onset of fatigue and lowers ratings of perceived exertion	Continuous (1-7 minutes) high-intensity exercise	**For 4 weeks:** **~3-6 g/day of β-alanine, in servings of ~ 0.8-1.6 g every 4 hours** **Followed by a maintenance dose:** **1.2 g/day**
Nitrate	• Lowers blood pressure and increases vasodilation • Increases transportation of molecules to/from working muscle • Improves mitochondrial efficiency, neurotransmission and calcium handling	Endurance exercise High intensity sprints High intensity, intermittent exercise	**2-4 hours pre-exercise:** **6.5-13 mmol / 400-800 mg (or 1-2 beetroot juice shots)**

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AIS (Australian Institute of Sport) Sports Supplement Framework: https://www.ais.gov.au/nutrition/supplements

Dietary supplements: https://www.gssiweb.org/en/sports-science-exchange/All/supplements

World Anti-Doping Code: https://www.wada-ama.org/en/resources/world-anti-doping-program/world-anti-doping-code

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