AIS SPORTS SUPPLEMENT FRAMEWORK
CAFFEINE

What is it?

Following ingestion, caffeine is rapidly absorbed and transported to all body tissues and organs where it exerts a large variety of effects. The mechanisms underpinning these effects may vary between individuals and include both positive and negative responses. Evidence of the use of caffeine to enhance sports performance has been developed over more than a century of scientific testing, with robust evidence[2] now confirming the following:

- Small caffeine doses (e.g. 2-3 mg/kg (~200 mg)) are effective at improving performance, irrespective of whether the caffeine is ingested before and during (in the case of endurance tasks) exercise.
- The major benefits of this dose of caffeine on exercise capacity and performance appear to be achieved by central nervous system effects, specifically those involving antagonism of adenosine receptors. These effects reduce the perception of fatigue and allow optimal pacing and skill/work outcomes to be maintained for a longer period.
- In addition, caffeine increases the mobilisation of fats from adipose tissue and at the muscle cell, can change to muscle contractility. While these effects exist, they are less likely to explain the magnitude of performance changes observed in the current literature.
- Individuals vary in their response to caffeine intake. Although caffeine may enhance sports performance in most, some individuals are non-responders and others may respond negatively to caffeine ingestions.
- Athletes should be made aware of the potential of these effects and practitioners should be encouraged to trial its use with athletes before use in major competitions.

Caffeine was removed from the World Anti-Doping Agency Prohibited List in 2004, allowing athletes who compete in WADA sanctioned sports to consume caffeine within their usual diets or for specific purposes of performance. This change was based on the recognition that caffeine enhanced performance at doses consistent with everyday use, and that monitoring caffeine intake via urinary caffeine concentration was not reliable. WADA continues to test urinary caffeine concentrations within its Monitoring Program to investigate patterns of misuse.

Pure or highly concentrated caffeine can be potentially lethal and hence pose an acute risks to consumers.

What does it look like and where is caffeine found?

Caffeine (1,3,7-trimethylxanthine), is a substance found naturally in the leaves, beans and fruits of a variety of plants, and is regularly consumed by ~90% of adults. The most common dietary source of caffeine is coffee, but tea, cola drinks, energy drinks, chocolate and specialised sports foods and supplements also contribute to regular intake. In its pure form, caffeine is a fine white powder, similar in appearance to icing sugar.

The most recent national data suggests the average intake of caffeine by adult Australians is ~175 mg/day (~2-2.5 mg/kg body mass/day) with at least 25% of the population consuming >230 mg/day (3+ mg/kg body mass/day).

A range of products provide caffeine in our everyday diets. Table 1 provides a summary of common foods, drinks and over-the-counter preparations available in Australia, while Table 2 provides a summary of products that are more specifically targeted to athletes. Important points to note are:

- The manufacture of caffeine containing products in Australia is regulated variously by Food Standards Australia New Zealand ("FSANZ") or the Therapeutic Goods Administration. Foods, which naturally contain caffeine and have a long history of use and consumer awareness/association with caffeine, such as tea, coffee and cocoa, are exempt from labelling requirements and the addition of these caffeine sources to other foods is allowed.
- The values for foods with naturally occurring caffeine (e.g. coffee, tea, guarana) are "typical" or "average" amounts. However, there can be a considerable range in the actual caffeine content of these products.
- Coffee can potentially provide a substantial dose of caffeine in a single serve. Studies of beverages purchased from commercial outlets have documented caffeine doses of >200 mg in a small volume caffeine beverage and >500 mg in a large volume beverage from specialty coffee franchises.
- The caffeine content of commercial coffee varies. This variability is evident when the same beverage is purchased from different locations of the same franchise, or the same beverage is purchased from the same location on different days. Therefore, it is difficult to predict or guarantee a dose of caffeine using commercial coffee as a source.

- Iced coffee and cold caffeinated drinks (i.e. frappes) can also contain a substantial dose of caffeine with a commercially available single serve providing up to 200 mg of caffeine.
- Cola drinks, energy drinks, sports foods and therapeutic goods represent an additional source of caffeine in the food supply and are a popular choice among specific population groups (e.g. adolescents and young adults). While cola drinks have been available for over a century, "energy" drinks are a more recent and increasingly popular caffeine source.
- The Australian Foods Standards Code allow for the addition of caffeine to cola drinks at a maximum level of 145 mg/L while energy drinks, known in the code as Formulated Caffeinated Beverages, can contain caffeine from all sources (caffeine and guarana) of up to 320 mg/L. Energy drinks must state their caffeine content on product labels.

The Australian Food Standards Code provides greater regulation of caffeine-added products than found in other countries. It restricts the development of new food products containing non-traditional sources of caffeine (including guarana) beyond the current provisions. In Aug 2019, FSANZ released a further review of "Pure and highly concentrated caffeine products" and recommended a further review of FSANZ Standard 2.9.4 – Formulated Supplementary Sports Foods. This review is currently underway.

Table 1: Caffeine content of common foods, drinks and therapeutic products (Australia)

Food or Drink	Serve	Caffeine Content (mg)
Instant coffee	250 ml cup	60 (12-169)*
Brewed coffee	250 ml cup	80 (40-110)*
Brewed coffee (same outlet on different days)	250 ml cup	130-282*
Short black coffee/espresso from variety of outlets	1 standard serve	107 (25-214)*
Starbucks Breakfast Blend brewed coffee	600 ml (Venti size)	415 (300-564)*
Iced coffee – Commercial "Loaded", "Extra Strong" varieties	500 ml bottle	170-200
Iced coffee – Commercial Standard varieties		85-140 depending on brand
Frappuccino	375 ml cup	90
Tea	250 ml cup	27 (9-51)*
Black tea	250 ml cup	25-110
Green tea	250 ml cup	30-50
Iced Tea	600 ml bottle	20-40
Hot chocolate	250 ml cup	5-10
Chocolate – milk	60 g	5-15
Chocolate – dark	60 g	10-50
Coca Cola#	375 ml can/600 ml bottle	36/58
Diet Coke	375 ml can/600 ml bottle	48/77
Pepsi	375 ml can/600 ml bottle	40/64
Red Bull energy drink#	250 ml /330 ml/500 ml can	80/106/160
V Energy drink	250 ml/350 ml/500 ml	78/109/155
Mother energy drink	150/300 ml/500 ml can	48/96/160
Monster energy drink	340 ml/500 ml can	109/160
Rockstar	500 ml can	160
No Doz (Australia)	1 tablet	100

Some carbohydrate-containing sports foods, such as sports drinks, gels and bars contain small amounts of caffeine – typically, 20-100 mg per serve (see Table 2). Two other supplement categories also typically contain a source of caffeine: Fat loss products and Pre-workout supplements. Table 2 provides examples of products available in Australia, which fall under the jurisdiction of Therapeutic Goods Administration. Concerns regarding these supplement categories include the lack of information on the caffeine dose provided by a typical serve of these products and the potential for large caffeine doses.

Table 2: Caffeine content of common sports foods and supplements (Australia)

Product	Serve	Caffeine content (mg)
Sports food		
Clif Shot	34 g sachet	25 (Citrus), 50 (Mocha) 100 (Espresso)
Clif Bar	68 g Bar	49 (Cool Mint)
Endura Sports Gels	35 g sachet	8.5
GU caffeinated sports gel	32 g sachet	20 (Tri-berry, Orange, Vanilla, Chocolate, Caramel, Nude, Mint Chocolate, Watermelon)
GU caffeinated sports gel	32 g sachet	40 (Jet Blackberry, Espresso, Macchiato)
Hammer Gel	33 g sachet	25 (Tropical), 50 (Espresso)
Koda Energy gel	45 g sachet	80 (Cappuccino, Cola Vanilla & Green Plum)
Maurten Gel100 Caf100	40 g sachet	100
PowerBar Isomax sports drink	50g Powder	75
PowerGel Hydro - caffeinated	67mL sachet	100 (Cola), 51 (Cherry & Mojito)
PowerGel Fruit - caffeinated	40 g sachet	50 (Mango-Passionfruit)
PowerGel Shots	60g pouch	75 (Cola)
Revvies Caffeine Mouth Strips	1 strip	40 (Original), 100 (Extra Strength)
SIS Go Energy+Caff Gel	40 g sachet	75 (Espresso, Citrus, Red Berry)
SIS Go Energy+Caff Bar	40 g Bar	75 (Espresso, Red Berry)
Pre-workout supplements*		
USPLabs Jack3D	15.9 g	387 (AC)
GAT Nitraflex	10.3 g	342 (AC)
BPM labs The One	13.5 g	314 (AC)
APS Morph 3	15.5 g	309 (AC)
Max's Beta pump	10 g	302 (AC)
Musclepharm Arnold Iron Pump	6 g	242 (AC)
Musclepharm Assault	14.5 g	234 (AC)
BSN N.O. Explode	18.5 g	193 (AC)
Cellucor C4 (explosive energy)	6.5 g	182 (AC)
Optimum Nutrition Gold Standard	10 g	180 (Tea/Coffee extract)
Vital Strength 16:00 Nitroxl	15 g	144 (Unknown)
Define-8	3.2 g	129 (AC)
Optimum Nutrition Essential Amino Energy	9 g	111 (Green Tea/Coffee extract)
BSc K-OS Gold Label	6 g	103 (AC)
Musashi Re-Activate	15 g	91 (AC)
Fat loss supplements†		
BPM Labs Annihilate	5 g	200
BSc Hydroxyburn Shred	5 g	47
BSc Hydroxyburn Shred Ultra	5 g	156
BSc Hydroxyburn Clinical	1 tablet	50
EHP Labs Oxyshred	4.5 g	150 (Raspberry)
Factionlabs Deficit	8 g	250
Optimum Nutrition Burn Complex	5 g	250

AC = Anhydrous (Pure) Caffeine, * values taken from2, †values taken from product label

How and when do I use it?

Over the last 15 years a large number of studies have refined our understanding of caffeine's performance enhancing effects. If there is a dose–response relationship between caffeine intake and exercise performance (i.e. the bigger the dose, the better the performance outcome), the plateau seems to occur at a dose of ~3 mg/kg or ~200 mg. This offers athletes (both male and female) the opportunity to consume caffeine for performance benefits at doses that are less likely to cause side effects such as increases in heart rate, impairments or alterations of fine motor control and technique, and anxiety or over-arousal), well within normal population caffeine use patterns, and from the caffeine doses provided by a range of well accepted foods and sports foods.

It appears that a variety of protocols of caffeine intake that can enhance performance. These include the consumption of caffeine before the exercise bout, spread throughout exercise, or late in exercise as fatigue is beginning to occur. Different protocols may achieve optimal performance outcomes even in the same sport or individual. Suitable or optimal protocols may be dictated by the specific characteristics of the event, the practical considerations of consuming a caffeine-containing product, and the individual characteristics/preferences of the athlete. Athletes intending to use caffeine to enhance sports performance should work with their high performance team providers to develop a protocol(s) and trial these in training or less important events to determine the protocol(s) which best suit their individual needs.

Performance benefits have been observed following caffeine administered in capsules, coffee, sports and energy drinks, gum, gels, bars and dissolvable mouth strips. Mouth rinsing with caffeine or aerosol caffeine administration appear less likely to produce an ergogenic effect. In addition, studies now show that benefits from caffeine occur soon after intake and are not reliant on the achievement of peak blood caffeine concentrations which typically occur around 60mins.

There is doubt about the value of withdrawing from caffeine use prior to using it for competition to "heighten" the subsequent effect on performance. Observations of a greater performance improvement following a period of caffeine abstinence may be an artefact – caffeine withdrawal may impair general well-being and performance and the apparent increase in benefits when caffeine is reintroduce is partly explained by the reversal of these negative effects. Well-designed studies show that there is no difference in the performance response to caffeine between non-users and users of caffeine, and that withdrawing athletes from caffeine does not increase the net improvement in performance achieved with caffeine supplementation.

While most studies of caffeine and performance have been undertaken in laboratories, (fewer investigations on elite athletes using field/real-life sports conditions), there is sound evidence that caffeine is likely to enhance the performance of a range of sports, including:

- Endurance sports (> 60 min)
- Brief sustained high-intensity sports (1-60 min)
- Team and intermittent sports – work rates
- Team and intermittent sports – skills and concentration
- Single efforts involving strength or power

In summary, athletes are able to ingest performance-enhancing doses (~200 mg) of caffeine from common foods/beverages. Athletes who want to use caffeine to enhance sports performance should develop supplementation protocols that use the lowest effective caffeine dose.

Are there any concerns or considerations?

Safety

Excessive caffeine intake has been linked with a number of health issues. Pure or highly concentrated caffeine can be potentially lethal and hence poses an acute risks to consumers. Death has been reported after a single dose of 3g of pure caffeine. As such, in 2019, the Therapeutic Goods Administration took steps to prevent the sale of pure-caffeine products within Australia. Other caffeine side-effects include increases in heart rate, impairments or alterations of fine motor control and technique, and anxiety or over-arousal.

In terms of caffeine within food products, various international health agencies consider caffeine to be a generally safe compound for to adults to consume, especially when low to moderate doses are ingested. These doses are commonly defined as

- ≤400 mg/day from all sources (except for pregnant individuals), and
- ≤200mg at any one time

The use of caffeine by children carries greater risk, and children <18 years are suggested to limit caffeine intake to <2.5 mg/kg/d.

We would advise that choosing caffeine from therapeutic sources such as No Doze is preferable over choosing caffeinated pre-workouts as these sports products can contain variable amounts of caffeine and also pose a risk of containing banned substances.

Sleep

Caffeine can affect sleep onset and quality, even at low levels of intake. This may interfere with the athlete's ability to recover between training sessions, or multi-day competitions. Given the half-life of caffeine is ~5 hours (i.e. about half the drug remains in your blood after this period), consideration should be given to the timing of caffeine intake relative to the need for sleep.

Dehydration

Small to moderate doses of caffeine have minimal effects on urine losses or the overall hydration in people who are habitual caffeine users. In addition, caffeine-containing drinks such as tea, coffee and cola drinks provide a significant source of fluid in the everyday diets of many people.

Genetics

The effects of caffeine vary markedly between individuals. Each athlete should make decisions about caffeine use based on experience of their own responsiveness and reactions, including side-effects. It remains unclear whether genetic differences related to caffeine metabolism or adenosine receptor density explain the contrasting performance effects[3].

Where can I find more information?

Sports Dietitians Australia

https://www.sportsdietitians.com.au/factsheets/supplements/caffeine

Gatorade Sports Science Institute

www.gssiweb.org/docs/default-source/sse-docs/spriet_sse_203_a03_final.pdf?sfvrsn=2

Supplement safety information

www.sportintegrity.gov.au/what-we-do/anti-doping/supplements-sport

References

1. McLellan, T., J. Caldwell, and H. Lieberman. (2016). A review of caffeine's effects on cognitive function, physical and occupational performance. Neuroscience and Biobehavioral Reviews, 71, 294-312.
2. Desbrow, B., et al. (2018). Caffeine content of pre-workout supplements commonly used by Australian consumers. Drug Test Anal, 11(3), 523-529.
3. Pickering, C. and J. Grgic. (2019). Caffeine and Exercise: What Next? Sports Med, 49(7), 1007-1030.

The Australian Institute of Sport (AIS) Supplement Framework is an initiative of the Australian High Performance Sport System. The AIS acknowledges the support of members of the National Institute Network (NIN) and National Sporting Organisations (NSO) and their staff in delivering content expertise. This information is intended to help athletes, coaches and scientists make evidence-based decisions about the use of supplements and sports foods. Before engaging in supplement use, we recommend that each individual refer to the specific supplement policies of their sporting organisation, sports institute or parent body, and seek appropriate professional advice from an accredited sports dietitian (**www.sportsdietitians.com.au**).

Athletes should be aware that the use of supplements may have doping implications. Athletes are reminded that they are responsible for all substances that enter their body under the 'strict liability' rules of the World Anti-Doping Code. Some supplements are riskier than others. The Sport Integrity Australia (SIA) app is a useful resource to help mitigate the risk of inadvertent doping by helping to identify supplements that have been batch-tested. The SIA App provides a list of more than 11,000 batch-tested products. We recommend that all athletes consult the educational resources of SIA regarding the risks associated with supplements and sports foods.. While batch-tested products have the lowest risk of a product containing prohibited substances, they cannot offer you a guarantee that they are not contaminated (**www.sportintegrity.gov.au/what-we-do/supplements-sport**).

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