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Caffeine and Exercise Performance

Caffeine may be the most widely used stimulant in the world. It is found in a variety of plants, dietary sources (including coffee, tea, chocolate, cocoa, and colas), and non-prescription medications. The average caffeine consumption in the USA is approximately 2 cups of coffee per day (200 mg); 10% of the population ingests more than 1000 mg per day. Caffeine is a socially acceptable, legal drug consumed by all groups in society.

Caffeine is often referred to as a nutritional ergogenic aid, but it has no nutritional value. Ingested caffeine is quickly absorbed from the stomach and peaks in the blood in 1-2 hours. Caffeine has the potential to affect all systems of the body, as it is absorbed by most tissue. The remaining caffeine is broken down in the liver and byproducts are excreted in urine.

CAFFEINE AND ENDURANCE EXERCISE PERFORMANCE

Laboratory studies from the 1970's suggested that caffeine enhanced endurance performance by increasing the release of adrenaline into the blood stimulating the release of free fatty acids from fat tissue and/or skeletal muscle. The working muscles use this extra fat early in exercise, reducing the need to use muscle carbohydrate (glycogen). The "sparing" of muscle glycogen made more available later in exercise to delay fatigue.

In the 1980's, many studies found that caffeine did not alter exercise metabolism, and implied that it had no ergogenic effect, without actually measuring performance. A few reports did examine caffeine and performance during endurance exercise and generally found no ergogenic effect. By the end of the decade, it was suggested that caffeine did not alter metabolism during endurance exercise and may not be ergogenic.

Recent work reported that ingestion of 3-9 mg of caffeine per kilogram (kg) of body weight one hour prior to exercise increased endurance running and cycling performance in the laboratory. To put this into perspective, 3 mg per kg body weight equals approximately one mug or 2 regular size cups of drip-percolated coffee; and 9 mg/kg = approximately 3 mugs of 5-6 regular size cups of coffee. These studies employed well-trained, elite or serious, recreational athletes. Studies with untrained individuals cannot be performed due to their inability to reliably exercise to exhaustion.

The mechanism to explain these endurance improvements is unclear. Muscle glycogen is spared early during submaximal exercise following caffeine ingestion (5-9 mg/kg). It is unknown whether glycogen sparing occurs as a result of caffeine's ability to increase fat availability for skeletal muscle use. Furthermore, there is no evidence supporting a metabolic component for enhancing performance at a low caffeine dose (3 mg/kg). Therefore, it appears that alterations in muscle metabolism alone cannot fully explain the ergogenic effect of caffeine during endurance exercise.

CAFFEINE AND SHORT-TERM EXERCISE PERFORMANCE

Research suggests that caffeine ingestion improves performance during short-term exercise lasting approximately 5 minutes at 90 to 100 percent of maximal oxygen uptake in the laboratory. This exercise intensity requires maximal provision of energy from both aerobic (oxygen requiring) and anaerobic (non-oxygen) sources. It is unknown if this finding applies to race situations. The reasons for the performance improvement may be a direct positive effect of caffeine on muscle anaerobic energy provision and contraction or a central nervous component related to the sensation of effort. Caffeine ingestion does not appear to improve sprint performance, but additional well-controlled laboratory and field studies are required to confirm this conclusion. Sprinting is defined as exercise that can be maintained from a few seconds to 90 seconds where most of the required energy is derived from anaerobic metabolism.

PRACTICAL ASPECTS OF CAFFEINE INJECTION

Caffeine Dose. Caffeine is a “controlled or restricted substance” as defined by the International Olympic Committee (IOC). Athletes are allowed up to 12 ug caffeine per milliliter of urine before it is considered illegal. The acceptable limit in sports sanctioned by the National Collegiate Athletic Association (NCAA) in the U.S. is 15 ug/ml urine. These high urinary limits are to allow athletes to consume normal amounts of caffeine prior to competition. A large amount of caffeine can be ingested before reaching the “illegal” limit. For example, if a 70 kg person rapidly drank about 3-4 mugs, or 5-6 regular size cups of drip-percolated coffee (~9 mg/kg bw) one hour before exercise, exercised for 1-1.5 hours and then gave a urine sample, the urinary caffeine level would only approach the limit (12 ug/ml). The odds of reaching the limit through normal caffeine ingestion are low, except where smaller volumes of coffee with very high caffeine concentrations are consumed. Therefore, an illegal urinary caffeine level makes it highly probable that the athlete deliberately took supplementary caffeine tablets or suppositories in an attempt to improve performance.

The optimal dose for maximizing the chance that exercise performance will be enhanced is ~3 – 6 mg/kg, where side effects are minimized and urine levels are legal. The side effects of caffeine ingestion include anxiety, jitters, inability to focus, gastrointestinal unrest, insomnia, irritability, and, with higher doses, the risk of heart arrhythmias and mild hallucinations. While the side effects associated with doses of up to 9 mg/kg do not appear to be dangerous, they can be disconcerting if present prior to a competition and may impair performance. Ingestion of higher doses of caffeine (10-15 mg/kg) is not recommended as the side effects worsen. It should also be noted that most studies have used pure caffeine rather than a caffeinated beverage or food. Thus, it is not certain that consuming the “equivalent dose of caffeine” as coffee, for example, will have the same result.

Diuretic Effect of Caffeine. Coffee and/or caffeine are often reported to be diuretics, suggesting that ingestion of large quantities could lead to poor hydration status prior to and during exercise.

However, the available literature does not support immediate diuretic effect as body core temperature, sweat loss, plasma volume and urine volume were unchanged during exercise following caffeine ingestion.

Ethical Considerations. It is easy for endurance athletes to improve performance “legally” with caffeine, as ergogenic effects have been reported with as little as 3 mg/kg body weight (bw). Even ingesting a moderate caffeine dose (5-6 mg/kg) is permissible. It has been suggested that caffeine should be banned prior to endurance competitions, requiring the athletes to abstain from caffeine approx. 48-72 hours before competition. This limitation would ensure that no athlete had an unfair advantage on race day, but would not prevent caffeine use in training. However, even if caffeine is banned in the future, what practice should athletes follow at present? For elite athletes, it is currently acceptable and reasonable to have their normal dietary coffee. However, if they deliberately take pure caffeine to gain an advantage on competitors, it is clearly unethical and is considered doping.



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An equally important issue is the use of caffeine by the average active teenager or adult. Caffeine's widespread use was demonstrated in a recent survey by the Canadian Centre for Drug Free Sport. The survey found that 27% of Canadian youths (11-18 years old) had used a caffeine-containing substance in the previous year for the specific purpose often enhancing athletic performance. Does caffeine act as a "gateway" drug for the young who then use dangerous substances? For the average, active teenager or adult who is exercising with the goals of enjoyment and self-improvement, using caffeine defeats these purposes. Proper training and nutritional habits are more sensible and productive approaches.

SUMMARY

Caffeine ingestion (3-9 mg/kg bw) prior to exercise increases performance during prolonged endurance exercise and short-term intense exercise lasting approx. 5 minutes in the laboratory. These results are generally reported in well-trained elite or recreational athletes, but field studies are required to test caffeine's ergogenic potency in the athletic world. Caffeine does not appear to enhance performance during sprinting lasting less than 90 seconds, although research in this area is lacking. The mechanisms for improved endurance have not been clearly established. Muscle glycogen sparing occurs early during endurance exercise following caffeine ingestion but it is unclear whether this is due to increased fat mobilization and use by the muscle. The positive effect of caffeine during exercise lasting approx. 5 minutes is not related to the sparing of muscle glycogen. The ergogenic effects of caffeine are present with urinary caffeine levels that are well below the IOC allowable limit (12 ug/ml). This raises ethical issues regarding caffeine use in athletics. Should the practice be condoned, as it is legal, or should it be discouraged, as it promotes the "doping mentality" and may lead to more serious abuse? One solution would be to add caffeine to the list of banned substances, thereby requiring athletes to abstain from caffeine ingestion 48-72 hours prior to competition and discouraging its use as a doping agent to increase performance in the average population.

Written for the American College of Sports Medicine by

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