The Ergogenic Effects of Caffeine During Sport and Exercise

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Introduction

There is no question that caffeine fuels the lives of countless people all around the world. More unbeknown, caffeine is used to fuel sport and exercise as well. Documentation of this goes back a long time but has become increasingly popular only in recent times. Most often, caffeine is used to help fuel endurance sports like cycling and running but have also been used to stimulate performance in team-sports. Cycling usually involves riders competing in races of varying lengths from shorter sprint-style races to other, longer races, consisting of riding over 100 miles at a time. Running events are usually performed in a similar fashion but over lesser distances. Popular distances are 5 kilometers, 10 kilometers, half marathons (13.1 miles) and full marathons (26.2 miles). Team sports usually consist of varying levels of activity conducted in a random stop-and-go manner. The most popular team-sports in the United States are Football, Baseball, Basketball, Hockey, and Soccer. However, as the controversy of performance-enhancing drugs in sports continues to rise, caffeine has been targeted as a drug that should possibly be removed from sports. Although the International Olympic Committee has recently lifted its ban on the drug, the NCAA currently bans the drug in their athletes if it is found to be at levels greater than 15 µg/ml in urine testing. Research using caffeine as the primary stimulant during exercise dates back to over 100 years ago; the general consensus is that caffeine does act as an ergogenic aid. On the contrary, some studies have shown that when caffeine is used in such ways, it actually provides no ergogenic effects (Bortolotti et. Al. 2014) and (Burke 2008). The problem is that there are many factors that contribute to caffeine's ability to act as an ergogenic aid. Most studies have focused and tested on factors such as the method of ingestion, personal tolerance, and type of physical activity (Bell & McLellan 2002) and (Sökmen et. Al. 2008). There are varying opinions on the efficiency and integrity of using caffeine stimulation in different sports and exercise but it is important to recognize that considerable research in this topic is ongoing. Once the physiological roles and underlying factors of caffeine in the body are fully understood, then further conclusions and recommendations can be drawn.

Literature Review

The majority of the literature used in this chapter focused on the use of caffeine as a possible performance-enhancing drug during exercise; cycling was the most prevalent form of exercise. Less commonly, some sources did address and test the use of caffeine during specific team-sports. Most of the studies were conducted in a highly controlled laboratory using populations that typically consisted of less than 20 college to middle-aged, white males and females. The independent variable was typically the amount of caffeine ingested by individual participants (3-9mg/ kg body weight). Examples of common dependent variables tested were perceived exertion, time to exhaustion, heart rate, and power output. The sources used in this paper provided research supporting the conclusion that caffeine works as an ergogenic aid as well as research showing no difference in exercise performance after caffeine consumption.

Caffeine is widely known to play a role in the body's central nervous system affecting mood, alertness, tiredness, and arousal. Although there are no certain mechanisms of exactly how caffeine stimulates the body, one of the most popular mechanism theories spotlights the role caffeine plays on the adenosine receptors. Some of the other accepted mechanisms of how caffeine may elicit ergogenic effects during physical activity include muscle glycogen sparing, maintaining higher dopamine levels, and a possible placebo effect (Graham 2001) and (Meeusen et. Al. 2013) and (Mitsumoto et. Al. 1990).

In a 2006 study by Wiles et. Al., eight healthy, well-trained, male cyclists were asked to perform a max-speed sprint of one kilometer in a controlled environment. The focus of this study was that they were given a specific dosage of caffeine according to body weight, one hour and 15 minutes before the one-kilometer trials. Data values for power, maximum power, average speed, and time were recorded. The results showed improvements in every category for seven of the eight cyclists during caffeinated time-trials. These results were very similar to another study conducted in a 2002 by Bell and McLellan. In this study, the dependent variable was tested to a greater degree by the addition of time intervals between ingestion and activity; i.e. the effects of caffeine on exercise in a prolonged amount of time after ingestion (1, 3, and 6 hours). The participants were again given a concentration of caffeine according to body mass. The study also emphasized the possible differences in effects in 13 typical users and eight non-users of the drug. Bell and McLellan concluded that caffeine provided ergogenic effects after the one and three-hour marks in both non-users and users, with a longer time to exhaustion in the non-users. One interesting note in this particular study was that both the typical users and non-users were asked to refrain from any caffeine consumption for 12 hours before each trial. Several studies further

support this cessation period concept by pointing out that tolerance, does not completely block the drug's effects. These studies emphasize the reduction of caffeine rather than complete elimination in order to avoid the effects of withdrawal (Graham 2001) and (Satel 2006) and (Sökmen, et. Al. 2006). Most studies involving sports like cycling, cross country, or track & field, focus on endurance performance under the influence of caffeine; results tend to trend in the direction of a performance increase. However, in another similar study, opposing results were found. This study included 13 healthy, male cyclists with at least two years of competitive cycling who received weight-based quantities of caffeine or a placebo. The cyclists were divided into a control and experimental group and asked to complete a 20-kilometer timed-trial race in a controlled environment. The results determined that there were no noteworthy differences in performance or perceived exertion between the two groups (Bortolotti et. Al. 2014).

Moving now to the more specific subject of this chapter: caffeine's ergogenic effect on athletic performance in team sports. Studies in this area have been much less common with more vague results. Few studies are able to achieve an experimental design that is controlled enough to produce accurate results while continuing to simulate the random stop-and-go nature of many team sports. In a 2006 study by Schneiker, et. Al. 10 male, moderately trained athletes were selected from the sports of Australian Rules Football (rugby), soccer, and hockey -- The authors of this study spent a vast amount of time assuring that an accurate and detailed simulation of the intermittent sprints during each of these sports was created -- The athletes were then blindly given either a placebo, or a caffeinated beverage according to body weight. Interestingly, all of the athletes perceived nearly identical work outputs and exertion even though those who received the caffeinated beverage consistently performed more work throughout each of the tests. One other possible point of interest in this study was that post-urinary analysis tests showed that none of the athletes who received the stimulant tested at levels higher than 12 μg/ml. Other sport-based studies have fixated on how caffeine affects the specific attributes that quality team-sport athletes possess. A good example of this is illustrated in a 2014 study by Jordan et. Al., in which elite level youth soccer players were tested according to reaction time, agility, and sprint speed. This study had many features of interest including the use of youth (post-pubescent) athletes, as well as testing reaction time for both dominant and non-dominant sides of the body. However, at the conclusion of the study, no significant differences for any of the tests, except the reaction time on the non-dominant side of the body, were found. Compare the results of this study to another team sport-based (basketball, rugby, and soccer), double blind study conducted by Paton et. Al. (2001). Athletes who ingested caffeine in this study also saw no increases in anaerobic attributes like short-term sprint speed. Similar studies that do not necessarily focus on the dynamics of sports but rather anaerobic or short-term exercise bouts, consistently found that there was no increase in power or strength as well (Greer et. Al. 1998) and (Jacobson & Edwards 1991). These studies tested sprints and resistance training, respectively, and actually pointed out that it is possible that caffeine may decrease performance in short-term exercises if used by the novice athlete.

All of these studies have analogous central concepts in their experiment that serve a major role in caffeine's physiological stimulation as well as in this chapter. These are typically the independent variables used in testing; timing of ingestion, tolerance to the drug, use of the drug as a habit, and dose of caffeine. These variables consistently expressed significant changes in the drugs effects. The drugs exercise-stimulating ability also appears dependent upon the type of

Figure 1. The caffeine content in various beverages. Note that the content is per beverage rather than per serving size. Other noteworthy beverages and products that contain caffeine include tea, chocolate, ice creams, chewing gums, various seeds, nuts, diet supplements, and diet pills.

physical activity being performed. Caffeine seemed to have the greatest influence on endurance sports and exercises, as stimulation was almost completely absent in anaerobic activities. On another note, caffeine's half-life is around four to six hours, and peak levels are found within the blood in blood plasma between 30 and 60 minutes from ingestion, depending on the person (Sökmen et. Al. 2008). The studies examined here took advantage of this by having participants ingest the drug about an hour prior to physical activity testing. Most commonly, caffeine being ingested around the world is in the form of energy drinks/sodas, coffee, and teas (Cox et. Al. 2002) and (Meeusen et. Al. 2013). The researchers in all of these projects focused on administering caffeine to the participants in a much more pure and weight-specific form than what is typically used in daily life. Caffeine in sodas and energy drinks may stimulate day-to-day activities, but has shown to have less of an effect in exercise and sports. This may be due to the extra additives in these products. However, some people blame this on the supposed diuretic effect of coffee and caffeine. Although, newer research suggests that this may not be physiologically accurate (Cureton et. Al. 2007) and (Armstrong et. Al. 2005). Some other commonly used caffeinated products are illustrated in Figure 1. Overall, the take away message of this literature review could be stated as such: Although some contrary results continue to be produced, the studies in this literature are a good representation of the vast amount of research demonstrating caffeine's performance enhancing ability.

The Physiological Effect of Caffeine

As discussed in the literature review, the specific mechanism as to how caffeine may provide an ergogenic effects is not specifically known, and generally, many different mechanisms are accepted as possibilities (Graham 2001). Most nutrients that are ingested are absorbed in the small intestine. However, since a portion of caffeine can absorb in the stomach, its effects can be felt rather quickly. Once caffeine reaches the blood stream it is spread throughout the entire body; its effects have been observed closest in the respiratory, skeletal muscular, cardiovascular, renal, and central nervous systems (Battram et. Al. 2008). Caffeine increases sympathetic activity, which elevates heart rate and constricts blood vessels,

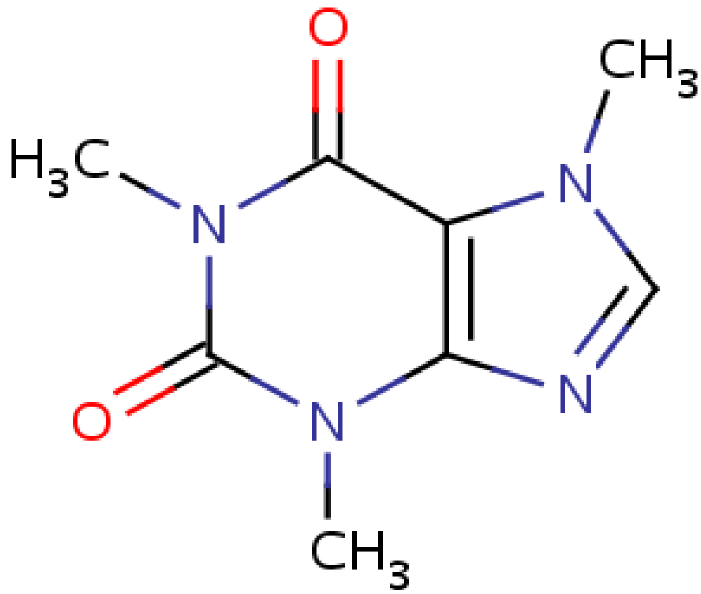


Figure 2. An ordinary caffeine molecule. Blocking adenosine receptors and stimulating serotonin are two ways caffeine has been noted to improve mood.

"I believe humans get a lot done, not because we're smart, but because we have thumbs so we can make coffee" –Flash Rosenberg

raising mean blood pressure. In the lungs, caffeine is a ventilatory stimulant, increasing bronchiole dilation and overall ventilation (Chapman & Mickleborough 2009). Furthermore, most of the studies trying to determine the specific mechanism that may induce ergogenic effects focus on caffeine's effect in skeletal muscle and the central nervous system.

In the central nervous system, caffeine stimulates the release of excess serotonin in the brain, which is sometimes known as a mood-enhancing neurotransmitter. The excess serotonin also increases sympathetic activity and decreases neuronal inhibitory activity. At a cellular level, this is observed through the adenosine receptors. Adenosine, which is known for quelling arousal and encouraging sleep, binds to these receptors and slows nerve cell activity. Caffeine counteracts this process, blocking the adenosine receptors, therefore speeding up cellular activity (Sökmen et. Al. 2008) Caffeine has also been observed to stimulate and maintain higher levels of dopamine in the brain. Because of this mechanism, caffeine is said to improve mental alertness, concentration, and reduce symptoms of mental fatigue (Meeusen et. Al. 2013).

In skeletal muscles, it has been shown to delay fatigue as well as creating a glycogen-sparing effect (Cox et. Al. 2002). Technically, this means that caffeine encourages the muscles to burn as much of the body's fatty acids as possible before tapping into the much more limited glycogen stores. Some studies speculate that this can produce a greater muscle contraction force as well. Moreover, these effects are not usually observed during anaerobic activities. The accepted theory behind this has to do with slow and fast twitch muscle fibers. Recall that slow twitch muscle fibers fire more slowly making them more efficient over time and are used for aerobic activities; they are most active during long bike rides, or runs. Fast twitch muscle fibers activate anaerobically, which can generate quick powerful bursts of speed or power but cause fatigue rather quickly. Early research has shown that adenosine receptors only exist in slow twitch muscle fibers (Greer et. Al. 1998) and

Remember…

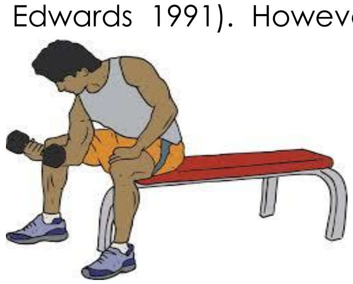
Although some are accepted more than others, there is no proven physiological mechanism that elicits caffeine's ergogenic effects.

(Mitsumoto et. Al. 1990). Thus, if adenosine receptors are the primary mechanism in the production of caffeine's ergogenic effects, it may explain why research showing performance enhancement in sprints and resistance training is almost non-existent.

Ergogenic Factors

As previously stated in this chapter, there is a long list of factors that influence caffeine's performance-enhancing mechanisms. These include the quantity of caffeine ingested, the time caffeine is ingested, the form of the caffeine ingested, how often caffeine is used, if there is a cessation period of use before physical activity, the type of activity the drug is being applied to, the skill level of the athlete involved, side effects of the drug, and even a possible placebo effect. Here, the major factors will be discussed in greater detail.

The most commonly accepted mechanism of why caffeine's ergogenic effects only show up in research using aerobic activities, usually relates to the adenosine receptors in slow-twitch muscle fibers (Greer et. Al. 1998). Since caffeine's ergogenic effects have been consistently demonstrated in aerobic, endurance activities, recall that the slow twitch muscle theory is only used to address the lack of drug's effects found in most team sports, and intermittent activity research (Jordan et. Al. 2014) and (Paton et. Al. 2001) and (Greer et Al. 1998) and (Jacobson & Edwards 1991). However, this research is almost always conducted using individuals who have simply reported to be physically active and volunteered for the study.



The exception to this of course, is the study directed by Jordan et. Al. (2014) using elite level youth soccer players; understand that caffeine in youth is a separate subject in which not much research has been devoted. Furthermore, specific research points to the theory that the motor unit in fast twitch muscle fibers, the primary mechanism in muscle contraction, is not conditioned to anaerobic activity in the novice athlete (Mitsumoto et. Al. 1990). Thus, in a professional resistance trainer or track & field athlete, it is possible that with their conditioned, fast twitch motor units may be able to benefit from caffeine's ergogenic effect. Nevertheless, research in professional level athletes is greatly limited.

One factor that may not have been specifically tested in every study but is sure to have played a role is caffeine habituation in the participants. If caffeine use is a habit of the participant, a tolerance to the drug is most likely to have developed. Tolerance has been shown to arise in regular caffeine users in as little as five or six days, but reducing caffeine intake three to four days before intense exercise or competition can allow the regular user to attain the same ergogenic benefits as a non-user (Graham 2001). Even though a three to four day time frame is recommended to allow caffeine tolerance to diminish, most studies had participants refrain from use for only 24 hours. Since caffeine is an addictive drug, complete elimination of the drug can lead to withdrawal effects – some of which have been reported to be severe in heavy users. Caffeine's physical dependence has been reported to cause things like headaches, nausea, bad moods, and inability to focus if use is discontinued. Such symptoms could definitely harm performance in exercise and sports, but moderate doses of the drug have been observed to reverse these effects. Thus, an extra emphasis is usually put on lowering caffeine dose rather than total exclusion. On a related topic, some people argue that regular caffeine users stop gaining the stimulation of caffeine over time and the effects felt are actually suppression of acute withdrawal symptoms. Most research attempting to address this theory is highly inconsistent (Satel 2006).

Relating the arguments of withdrawal suppression to the ergogenic effects of caffeine in exercise and sports creates another topic of controversy. Some people maintain the position that the negative side effects of caffeine and caffeine withdrawal can do more harm than good. Most people bring up the point that caffeine has a diuretic effect that may lead an excessive passage of urine and dehydration. A very interesting study by Armstrong et. Al. (2005), concluded that there was no unusual levels of dehydration found after 11 consecutive days of moderate caffeine use; other studies have found similar results (Sökmen et. Al. 2008).

Arguably, the most controlled factor in all of the research that went into writing this chapter was the dosage of caffeine administered to participants during experiments. Unless the form of caffeine was explicitly being tested, it was almost always ingested in a more pure and consistent pill, or powdered form according to individual body weights. Applying caffeine dosage per kilogram of body weight attempts to account for participants varying basal metabolic rates. Although caffeine in commercial products has shown to have less of an effect on exercise performance, some researchers believe these effects can still be achieved if greater amounts are consumed (Cureton et. Al. 2007). In order to achieve an ergogenic effect from caffeine, a dose of 3-9 mg per kilogram of body weight is standard. Ignoring tolerance for the moment, it would take the consumption of around five ordinary cans of Mountain Dew, or three cans of Red Bull in a short period of time, in order for a 70 kg individual to achieve these effects. However, consuming large amounts of sodas and energy drinks brings about greater health concerns and other exercise hindrances; this is not encouraged. Therefore, the best option for the average individual seeking ergogenic effects may be a classic cup of coffee, or more concentrated serving of espresso. Much like other drugs, however, caffeine has a toxic limit. The Food and Drug Administration recognizes an overdose of caffeine to be ingesting an amount in excess of 10 grams. Although ingesting this amount in a small time frame would be nearly impossible with any commercial products, much lower levels could still bring about undesirable symptoms.

The efficiency of caffeine's ergogenic use in sports and exercise depends on a number of intrinsic and extrinsic details. Further studies should be conducted to provide more detailed research on factors such as use in professional athletes, or combining caffeine with other dietary supplements containing creatine or amino acids. However, evidence is strong that the most vital factors affecting performance enhancement are the time and cessation period involved in use, as well as the dosage of the drug used.

Considerations for Athletes

Given the number of factors and possible mechanisms that affect caffeine's ability to be an ergogenic aid, there are many considerations for athletes thinking about using the drug.

- Caffeine should be taken no less than an hour before exercise or competition
- A regular user should decrease use of caffeine three to four days prior to exercise or competition; be aware of the side effects of withdrawal.
- A non-user should never try caffeine for the first time on the day of competition; experiment in practice.

- Recall that caffeine’s effects are documented to work best in an endurance sport rather than a stop-and-go sport.
- Take into account that the effects of caffeine can vary from person to person

Lastly, an important consideration that many people tend to forget about is the simple fact that caffeine is a performance-enhancing drug. Thus, under the right conditions, it can provide an edge over a competitor whom may choose to abstain from the drug. Some people question the IOC’s decision to remove caffeine from the list of banned substances given the fractional differences found in Olympic time-trial based sports. Although, it takes less than the considered “doping” amount to provide ergogenic effects, so abuse can be difficult to identify. Tests have shown that it takes large amounts of caffeine in an already regular user of the drug to test higher than the NCAA limit on the drug (Schneiker et. Al. 2006). However, make sure to know the rules on caffeine use in specific events.

References

1. Armstrong, L.E., Pumerantz, A.C., Roti, M.W., Judelson, D.A., Watson, G., Dias, J.C., So¨kmen, B., Casa, D.J., Maresh, C.M., Lieberman, H., and Kellogg, M. (2005). Fluid, electrolyte and renal indices of hydration during eleven days of controlled caffeine consumption. *International Journal of Sport Nutrition and Exercise Metabolism, 15*(3), 252–265. http://webcache.googleusercontent.com/search?q=cache:lon4fIBGKuIJ:www.researchgate.net/publication/7628664_Fluid_electrolyte_and_renal_indices_of_hydration_during_11_days_of_controlled_caffeine_consumption/links/09e4150bf9c40a8468000000+&cd=2&hl=en&ct=clnk&gl=us&client=safari

2. Battram, D. S., Dela, F., Graham, T. E., Sohemy, A. E., & Thong, F. S. L. (2008). Does caffeine alter muscle carbohydrate and fat metabolism during exercise?; coffee and caffeine: The relationship with cancer, diabetes, and cardiovascular disease, presented at the can. soc. for clin. nutrition's annual meeting. *Applied Physiology, Nutrition, and Metabolism, 33*, 1311+. Full Text

3. Bell, D. G., & McLellan, T. M. (2002). Exercise endurance 1, 3, and 6h after caffeine ingestion in caffeine users and nonusers. *Journal of Applied Physiology, 93*(4), 1227-1234. Retrieved from SCOPUS database. Full Text

4. Bortolotti, H., Altimari, L. R., Vitor-Costa, M., & Cyrino, E. S. (2014). Performance during a 20-km cycling time-trial after caffeine ingestion. *Journal of the International Society of Sports Nutrition, 11*(1) Full Text

5. Burke, L. M. (2008). Caffeine and sports performance. *Applied Physiology, Nutrition and Metabolism, 33*(6), 1319-1324. Retrieved from SCOPUS database. Full Text

6. Chapman, R.F., & Mickleborough, T.D. (2009). The effects of caffeine on ventilation and pulmonary function during exercise: an often-overlooked response. *The Physician and sportsmedicine, 37*(4), 97-103. Abstract

7. Cox, G. R., Desbrow, B., Montgomery, P. G., Anderson, M. E., Bruce, C. R., Macrides, T. A., et al. (2002). Effect of different protocols of caffeine intake on metabolism and endurance performance. *Journal of Applied Physiology, 93*(3), 990-999. Retrieved from SCOPUS database. Full Text

8. Cureton, K. J., Warren, G. L., Millard-Stafford, M. L., Wingo, J. E., Trilk, J., & Buyckx, M. (2007). Caffeinated sports drink: Ergogenic effects and possible mechanisms. *International Journal of Sport Nutrition and Exercise Metabolism, 17*(1), 35-55. Retrieved from SCOPUS database. http://webcache.googleusercontent.com/search?q=cache:cfzmNs-HE2kJ:www.researchgate.net/profile/Kirk_Cureton/publication/6369544_Caffeinated_sports_drink_ergogenic_effects_and_possible_mechanisms/links/0c960516a8e9dafc9a000000+&cd=2&hl=en&ct=clnk&gl=us&client=safari

9. Graham, T. E. (2001). Caffeine and exercise metabolism, endurance and performance. *Sports Medicine, 31*(11), 785-807. Retrieved from SCOPUS database. Full Text

10. Greer, F., McLean, C., & Graham, T.E. (1998) Caffeine, performance, and metabolism during repeated Wingate exercise tests. *Journal of Applied Physiology, 85*, 1502–1508. Full Text

11. Jacobson, B.H., & Edwards, S.W. (1991) Influence of two levels of caffeine on maximal torque at selected angular velocities. *Journal of Sports Medicine and Physical Fitness, 31*(2): 147–153. Abstract

12. Jordan, J. B., Korgaokar, A., Farley, R. S., Coons, J. M., & Caputo, J. L. (2014). Caffeine supplementation and reactive agility in elite youth soccer players. *Pediatric Exercise Science, 26*(2), 168-176. Full Text

13. Meeusen, R., Roelands, B., & Spriet, L. L. (2013). Caffeine, exercise and the brain. *Nestlé Nutrition Institute Workshop Series, 76*, 1-12. Retrieved from SCOPUS database. Full Text

14. Mitsumoto, H., Deboer, G.E., Bunge, G., Andrish, J.T., Tetzlaff, J.E., & Cruse, R.P. (1990) Fiber-type specific caffeine sensitivities in normal human skinned muscle fibers. *Anestesiology, 72*(1), 50-54. Full Text

15. Paton, C. D., Hopkins W.G., & Vollebregt, L. (2001) Little effect of caffeine ingestion on repeated sprints in team-sport athletes. *Medicine & Science in Sports & Exerc*ise, *33*(5), 822-825. http://ovidsp.tx.ovid.com/sp-3.13.1a/ovidweb.cgi?QS2=434f4e1a73d37e8c6114a63cc85fea0981b84f1f53b15a3ad20c6ada0562041a93afbde0427be87b647b7dfc74f470bc6c36b1fd24eae31e71ec97221e2dfb0996c895feef19d26c91dacf9acc278267fbfbde66877ee4d98bba264534e220d048057b6eab5f55461bdb161d050d736a77b451bd8623603bcecdc73d1f582480e04eaa181821c23687d00f056b069cd3ee3d23fa589b8008c04e42bfeaa38080a77346fd032d1994a1bf553adcd9724dfae09ce62b9a999eba2a65b13dee0c764ca415c5fd49ce43cfb257587d0c27612e87ad2dcbd1f4c611321c6e95db0e349177c4af0db2aa19040a56488c5c5b67d22365f81258774e7855309e0c9b09c6c6733aa49fe30b0e62865a4dd74ebb84a5938e300124baaefa60634bd62f3740af15d6f4c8b04a7f856fc887a4db3c5156d589183c36d6e1fe67b5446a43f4efb315750878984810f20ccdc0d974cff2

16. Satel, S. (2006). Is caffeine addictive?—A review of the literature. *American Journal of Drug & Alcohol Abuse, 32*(4), 493-502. Full Text

17. Schneiker, K. T., Bishop, D., Dawson, B., & Hackett, L. P. (2006). Effects of caffeine on prolonged intermittent-sprint ability in team-sport athletes. *Medicine Science in Sports & Exerc*ise*, 38*(3), 578 -585. http://ovidsp.tx.ovid.com/sp-3.13.1a/ovidweb.cgi?WebLinkFrameset=1&S=AHKHFPMBJHDDLHFHNCLKHGDCDGBMAA00&returnUrl=ovidweb.cgi%3f%26Full%2bText%3dL%257cS.sh.27.28%257c0%257c00005768-200603000-00025%26S%3dAHKHFPMBJHDDLHFHNCLKHGDCDGBMAA00&directlink=http%3a%2f%2fgraphics.tx.ovid.com%2fovftpdfs%2fFPDDNCDCHGFHJH00%2ffs046%2fovft%2flive%2fgv023%2f00005768%2f00005768-200603000-00025.pdf&filename=Effects+of+Caffeine+on+Prolonged+Intermittent-Sprint+Ability+in+Team-Sport+Athletes.&pdf_key=FPDDNCDCHGFHJH00&pdf_index=/fs046/ovft/live/gv023/00005768/00005768-200603000-00025

18. Sökmen, B., Armstrong, L. E., Kraemer, W. J., Casa, D. J., Dias, J. C., Judelson, D. A., et al. (2008). Caffeine use in sports: Considerations for the athlete. *Journal of Strength and Conditioning Research, 22*(3), 978-986. Retrieved from SCOPUS database. Full Text

19. Wiles, J. D., Coleman, D., Tegerdine, M., & Swaine, I. L. (2006). The effects of caffeine ingestion on performance time, speed and power during a laboratory-based 1 km cycling time-trial. *Journal of Sports Sciences, 24*(11), 1165-1171. Full Text