KOMOROWSKI, Marcin, JANISZEWSKI, Michał, PELCZARSKA, Aleksandra, KACZOROWSKI, Rafal, FORENC, Tomasz, HUNIA, Jaromir, GÓRNY, Julia, JUREK, Jonasz and KAPCIAK, Alicja. Can Caffeine Be an Effective Ergogenic Aid in Combat Sports? A Comprehensive Review. Journal of Education, Health and Sport. 2025;77:57144. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.77.57144
https://apcz.umk.pl/JEHS/article/view/57144

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 18.12.2024. Revised: 15.01.2025. Accepted: 17.01.2025. Published: 18.01.2025.

Can Caffeine Be an Effective Ergogenic Aid in Combat Sports? A Comprehensive Review

Marcin Komorowski[1], Michał Janiszewski[2], Aleksandra Pelczarska[3], Rafał Kaczorowski[4], Tomasz Forenc[5], Jaromir Hunia[6], Julia Górny[7], Jonasz Jurek[8], Alicja Kapciak[9]

1. **Marcin Komorowski**

Międzylesie Specialist Hospital, Bursztynowa 2, 04-749 Warsaw, Poland

https://orcid.org/0009-0009-1423-7176

mkomorowski16@gmail.com

2. **Michał Janiszewski**

Mazovian "Bródnowski" Hospital, Ludwika Kondratowicza 8, 03-242 Warsaw, Poland

https://orcid.org/0009-0007-8932-3808

1michal.janiszewski@gmail.com

3. **Aleksandra Pelczarska**

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

https://orcid.org/0009-0006-3505-1416

olapelczarska223@gmail.com

4. **Rafał Kaczorowski**

Mazovian "Bródnowski" Hospital, Ludwika Kondratowicza 8, 03-242 Warsaw, Poland

https://orcid.org/0009-0004-7042-114X

rafal.kaczorowski1202@wp.pl

5. **Tomasz Forenc**

Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland

https://orcid.org/0009-0007-9290-3571

forenctomasz@gmail.com

6. **Jaromir Hunia**

National Medical Institute of the Ministry of the Interior and Administration, Wołoska 137, 02-507 Warsaw, Poland

https://orcid.org/0000-0003-3596-0987

jaromirhunia@gmail.com

7. **Julia Górny**

Mazovian "Bródnowski" Hospital, Ludwika Kondratowicza 8, 03-242 Warsaw, Poland

https://orcid.org/0009-0008-5363-1590

Gornyjulia1@gmail.com

8. **Jonasz Jurek**

National Medical Institute of the Ministry of the Interior and Administration, Wołoska 137, 02-507 Warsaw, Poland

https://orcid.org/0000-0001-9567-8663

jurekjonasz@gmail.com

9. **Alicja Kapciak**

National Medical Institute of the Ministry of the Interior and Administration, Wołoska 137, 02-507 Warsaw, Poland

https://orcid.org/0009-0000-0655-8820

Ala.kapciak@gmail.com

ABSTRACT

Introduction: Caffeine, a well-known stimulant, is commonly used by athletes to enhance performance across various sports, including combat sports. Its ergogenic properties, such as improved strength, endurance, and cognitive function, have been well documented in the literature. This paper explores the effects of caffeine supplementation on combat sports, specifically in disciplines such as judo, jiu-jitsu, taekwondo, and boxing. The impact of different doses of caffeine on performance in these sports is examined, along with potential risks, limitations, and considerations for its use.

Aim of Study: The primary aim of this study is to analyze the effects of caffeine on performance in combat sports, considering various factors such as optimal dosage, timing, and the impact of habitual caffeine consumption. Additionally, this paper evaluates the potential adverse effects, including anxiety, sleep disturbances, and cardiovascular concerns, as well as the considerations regarding caffeine's status as a banned substance in sports.

Material and methods: A review of the literature on caffeine and its effect was performed using the PubMed database.

Results and Conclusions: Caffeine supplementation consistently enhances performance in combat sports. Doses ranging from 3–6 mg/kg were found to improve strength, endurance, and reaction times across various combat sports, with higher doses being more effective for elite athletes. However, habitual caffeine consumption may diminish responsiveness to caffeine’s ergogenic effects. Caffeine’s potential adverse effects, such as anxiety, insomnia, and increased heart rate, were reported, with gender differences in sensitivity. While caffeine’s ergogenic effects are well-established, its use should be personalized, considering individual responses and training status. Furthermore, caffeine's legal status and potential interactions with other substances, such as alcohol and medications, must be considered in competitive settings.

KEYWORDS: CAFFEINE; COMBAT SPORTS; ATHLETES; SUPPLEMENTATION;

1. INTRODUCTION

OVERVIEW OF COMBAT SPORTS AND THE PHYSIOLOGICAL DEMANDS OF THE DISCIPLINE.

Human civilizations and cultures have engaged in combative activities associated with warfare for millennia. Today, modern versions of these controlled activities, collectively termed “combat sports”. Combat sports take a significant place in sport today, being part of many international multi-sport events (e.g., Olympic Games and Continental Games), as well as having their exclusive event, the World Combat Games and each sport’s world championships. They are predominant events at the Olympic Games, where they comprise approximately 16% of the total medals awarded[1]. There are also an increasing number of professional combat sports with global audiences. The growing popularity of professional combat sports and their importance at the Olympic games have led to an increase in scientific studies that characterize the physical, physiological, nutritional, biomechanical and training strategies of combat sports athletes. These studies characterize combat sports as high-intensity sports which require training strategies to develop the high-intensity capabilities of athletes[2].

In almost all combat sports, athletes are classified according to their body mass so the matches are more equitable in terms of body size, strength and agility. However, many athletes acutely reduce body mass in an attempt to get an advantage by competing against lighter, smaller and weaker opponents[3]. Combat sports arguably contain unique characteristics in comparison to other sports: one must directly attack the opponent's body and the attack can be conducted simultaneously[1].

Most combat sports require a high level of technique, tactical excellence and physical fitness, especially strength, aerobic fitness, muscle power, and speed. In professional and amateur combat sports, participants can either strike an opponent using their fists, elbows, knees, head or feet; wrestle, throw, or pin an opponent on the ground; or grapple with an opponent in an effort to manipulate their body in order to perform joint locks and chokes. Therefore, in general, combat sports have been classified as striking (e.g., boxing, karate, taekwondo), grappling (e.g, Brazilian jiu-jitsu, judo, wrestling) or mixed (e.g., hapkido, jujutsu) sports, depending on their technical actions and rules[1]. In sanctioned and organized combat sports, contests are won by scoring a knockout, submission, technical knockout (referee or corner stopping the contest), or judges awarding points for superior technical ability and contest control[2].

In general, the greater the potential duration of a contest and the total number of 'attacks', the greater the requirement for well-developed aerobic capacity. Combat sports that are shorter in duration and are comprised primarily of grappling or wrestling tend to require relatively lower aerobic capacity. Nevertheless, a greater aerobic capacity has been related to a higher standard of performance in boxing, wrestling, and judo; however, some studies indicate no difference between standards[4]. This is somewhat expected, because although combat sport athletes require well-adapted aerobic energy systems, these sports also place considerable demands on anaerobic and neuromuscular systems during competition[2].

BACKGROUND ON CAFFEINE AS AN ERGOGENIC AID.

Many studies have been conducted looking at caffeine as an ergogenic aid. Most of the beneficial effects of caffeine have been shown in relation to alertness and neurocognitive performance, particularly in periods of sleep deprivation. Caffeine has also been implicated with having an analgesic as well as antinociceptive effect.

Most of the studies looking at caffeine in improving exercise or athletic performance of focused on endurance, submaximal exercise activities such as running and cycling. In these situations, caffeine has generally been shown to improve or sustain exercise performance, typically through an increase in the duration of the exercise or a decreased perception of exertion. In cycling, caffeine has been shown to increase time to exhaustion at 85% VO2max and decrease times to finish a fixed period of activity. Increased times to exhaustion have been seen in running as well as decreased times to run set distances. It appears that the ergogenic effect of caffeine occurs regardless of the timing of intake (either before or during the event). The effect of caffeine intake appears to be prolonged to as much as 6 hours following ingestion. This ergogenic effect is seen at a similar magnitude with both a one-time ingestion prior to exercise as well as with multiple smaller, but equal dosages given throughout a period of prolonged exercise. An interesting finding is that the ergogenic effect of caffeine is more pronounced in nonusers (< 50 mg daily) compared with regular users (> 300 mg daily) of caffeine. This is most likely explained by the upregulation of adenosine receptors with the regular consumption of caffeine.

The effect of caffeine on acute, high-intensity exercise is less clear. In the majority of studies that look at caffeine as an ergogenic aid, the caffeine is consumed in capsule form. As already discussed, by far the most common form of caffeine consumption is coffee. Graham et al. looked at the ergogenic potential of caffeine ingested in the form of coffee. The plasma concentrations of caffeine were similar whether ingested in the form of coffee or capsule. However, enhancement of endurance was seen only when caffeine was consumed independent of coffee. Likely, there are substances in coffee that antagonize the ergogenic potential of caffeine. Another source of caffeine that has been studied in terms of its ergogenic potential is caffeinated soft drinks. There is a practice among some endurance athletes to use a “defizzed” soft drink as a replacement for sports drinks during the latter stages of such events, believing that the caffeine intake produces an ergogenic effect. A study out of Australia suggests that the use of Coca-Cola (CocaCola, Atlanta, GA) produces an ergogenic effect similar to that of more conventional forms of caffeine intake. These findings are of undetermined significance, however, as the dose of caffeine consumed through Coca-Cola in this study are less than dosages of caffeine previously proven to be ergogenic.

Potential adverse effects: Caffeine can potentially cause some adverse effects. Reported effects at moderate doses include locomotor agitation, tachycardia, diuresis, insomnia, irritability, and increased anxiety. Severe caffeine toxicity has been linked to seizures and arrhythmias. In addition, it has been well documented that caffeine produces a withdrawal syndrome with cessation of repeated use. This can occur even with repeated usage at low dosages. Studies have demonstrated that withdrawal symptoms can occur with cessation of caffeine use for a short time period—as soon as 3 days after administration in novel users and as soon as 12 hours in habitual users. Common symptoms of caffeine withdrawal include headache, irritability, increased fatigue, drowsiness, decreased alertness, difficulty concentrating, and decreased energy and activity levels. Symptoms can be mild to moderate in severity. Fortunately, withdrawal symptoms are generally short-lived. Some of these adverse effects that have been mentioned could prove deleterious to athletes. Several studies have shown that caffeine can increase core body temperature. Increased diuresis with a concomitant decrease in body weight has also been demonstrated after administration of caffeine. These affects could prove to be harmful to athletes training in high ambient temperatures[5].

Caffeine is the most commonly consumed drug in the world, and athletes frequently use it as an ergogenic aid. It improves performance and endurance during prolonged, exhaustive exercise. To a lesser degree it also enhances short-term, high-intensity athletic performance. Caffeine improves concentration, reduces fatigue, and enhances alertness. Habitual intake does not diminish caffeine's ergogenic properties[6].

2. THE MECHANISMS OF CAFFEINE ACTION IN THE BODY

CAFFEINE METABOLISM AND INDIVIDUAL VARIABILITY:

There is a large interindividual variability in caffeine consumption and in its effects on the human body. Various factors that could contribute have been identified over the years, including age, sex, hormones, type of activity, coingestion with food. Caffeine also interacts with many medications[7].

Smoking of cigarettes and other inducers of aryl hydrocarbon hydroxylase tend to enhance the caffeine metabolism; pregnancy, the use of oral contraceptives, and various kinds of liver disease prolong the caffeine half-life[8].

The pharmacokinetics of caffeine are highly variable among individuals due to a polymorphism at the level of the CYP1A2 isoform of cytochrome P450, which metabolizes 95% of the caffeine ingested. Moreover there is a polymorphism at the level of another critical enzyme, N-acetyltransferase 2. At the pharmacodynamic level, there are several polymorphisms at the main brain target of caffeine, the adenosine A2A receptor. Genetic studies, including genome-wide association studies, identified several loci critically involved in caffeine consumption and its consequences on sleep, anxiety, and potentially in neurodegenerative and psychiatric diseases[7].

In the last two decades or so, numerous genetic studies aimed at clarifying how the genetic variability in the enzymes metabolizing caffeine (like CYP1A2 and N-acetyltransferase 2) and in the expression of adenosine receptors, mainly the A2A receptor underlying most of the physiological effects of caffeine in the body and brain, might underlie the pharmacokinetics and pharmacodynamics of caffeine and hence the sensitivity of different population subsets to the effects of caffeine ingestion[7].

However, according to Tian et al., intraindividual variation in caffeine metabolism is ≤30%, regardless of CYP1A2 genotype, sex, age, oral contraceptive use, or smoking status[9].

PHYSIOLOGY OF CAFFEINE – HOW IT WORKS IN THE BODY?

Caffeine (1,3,7-trimethylxanthine) is a xanthine which acts in the body's cells by different mechanisms of action and on a wide range of molecular targets. It intervenes as: an antagonist of the adenosine receptors (caffeine binds to adenosine receptors, which in turn block the binding of adenosine to its receptor); inhibitor of phosphodiesterase enzymes (it stimulates the accumulation of cAMP by preventing it from being enzymatically broken down, therefore stimulates the release of hormones such as dopamine, epinephrine, and noepinephrine[10]); sensitizer of calcium liberation channels (xanthines increase the release of intracellular calcium through activation in consort with calcium of the ryanodine-sensitive calcium release channels of the endoplasmic and sarcoplasmic reticulum); and GABA receptor antagonist[11].

The blockage of adenosine receptors indirectly affects the release of neurotransmitters such as acetylcholine, serotonin, glutamate, gamma-aminobutyric acid (GABA) (metabolites of caffeine, though less understood, show ergogenic potential as receptor antagonists to the calming inhibitory neurotransmitter - aminobutyric acid (GABA) and promoters of intracellular calcium release to increase muscular firing speed[11]), dopamine (adenosine inhibits the release of dopamine, thereby reducing mental alertness and motivation important in athletic competitions, therefore caffeine's antagonism of adenosine prevents this effects by enhancing dopamine availability[12, 13] norepinephrine, epinephrine (caffeine also promotes the release of the powerful stimulant epinephrine from the adrenal glands, which speeds the rate of muscle contraction, increases heart rate, and increases release of free fatty acids for energy[14]). An influx in these neurotransmitters alters mood, memory, alertness, and cognitive function[10].

Caffeine shows various effects and mechanisms of action in vascular tissue. In endothelial cells, it increases intracellular calcium stimulating the production of nitric oxide through the expression of the endothelial nitric oxide synthase enzyme. Nitric oxide is diffused to the vascular smooth muscle cell to produce vasodilation. In vascular smooth muscle cells its effect is predominantly a competitive inhibition of phosphodiesterase, producing an accumulation of cAMP and vasodilation. In addition, it blocks the adenosine receptors present in the vascular tissue to produce vasoconstriction[15].

EFFECTS ON THE CENTRAL NERVOUS SYSTEM AND PERIPHERAL FUNCTIONS

Caffeine has central nervous system stimulating properties (in the brain, adenosine and adenosine receptors regulate the release of neurotransmitters and play an important role in the regulation of sleep, arousal, cognition, memory, and learning[16, 17]), it is diuretic (adenosine receptors antagonism increases glomerular filtration rate by opposing adenosine-mediated vasoconstriction of renal afferent arterioles and inhibits sodium reabsorption in proximal tubules[18], decreases fatigue, enhances mental focus and athletic performance, and presents thermogenic effects. There is also evidence suggesting that the consumption of caffeine seems to reduce caloric intake, which is why it may contribute to weight loss[17].

The central ergogenic effect is not likely related to the ability of caffeine to promote wakefulness but could be due to an increase in the pain and effort perception threshold. There is no evidence that caffeine alters peripheral nerve conduction velocity or neuromuscular transmission[19], however according to Williams caffeine enhances neuromuscular transmission and improves skeletal muscle contractility at the cellular level[14]. Studies have shown that caffeine can have a direct effect on skeletal muscle that could be ergogenic[20]. They also suggest that caffeine can enhance contractile force during submaximal contractions by potentiating calcium release from the ryanodine receptor, not by altering sarcoplasmic excitability. Furthermore, the potentiation of force during submaximal electrical stimulation is identical in habitual and nonhabitual caffeine consumers[19]. In contrary to Tarnopolsky's study, which appear to focus on isometric exercise; dynamic contractions at different speeds, which was the subject of Bazzucchi et al.'s trial, indicated the improvement of muscle performance during short-duration maximal dynamic contractions and mean muscle fiber conduction velocity, therefore proved that there is an effect of caffeine on motor unit recruitment[21]. Moreover, this suggests that impact of caffeine on muscle function depends on the type of exercise.

3. CAFFEINE AND PERFORMANCE IN COMBAT SPORTS

Judogi dynamic strength endurance test comprises of holding on judogi involved around the bar and performing the maximal number of repetitions from an elbow fully extended to an elbow flexed until voluntary failure. When experienced judo and jiu-jitsu athletes ingested of 5mg/kg caffeine 60 minutes before it, they achieved improvement by 5%, when compared to placebo. Caffeine also affected maximal isometric handgrip strength by 7%[22]. Special judo fitness test (SJFT) is based on executing special throw type called *Ippon-seoi-nage* ("one arm over the back throw") in set amount of time. Consumption of 5mg/kg of caffeine before performing it was found to be helpful in increasing number of throws and decreasing fatigue index in comparison to placebo in high-level judo athletes[23]. Lower dose of 4mg/kg in similar setting was also established as advantageous in SJFT, when it was performed by underage judoists (16.1 ± 1.4 yrs.)[24]. In adult highly-trained judo professionals doses of 6 to 9mg/kg proved to be more efficient than 3mg/kg or placebo in enhancing SJFT performance. Moreover habitual usage of more than 160mg of caffeine per day came out to lower responsiveness to supplementation. In such individuals only dose of 9mg/kg was efficient[25]. On the other hand, different study conducted by Felippe et al. (2016) using dose of 6mg/kg before 3 sets of SJFT, found that only caffeine together with sodium bicarbonate, not alone, improved total number of throws[26]. Interestingly it was shown that in karate athletes supplementation of caffeine in dose of 6mg/kg and sodium bicarbonate alone, as well as together achieved better performance in karate-specific aerobic test than control. Moreover, there were no statistical differences between groups other than between control[27]. Previously mentioned researches tested ingestion of caffeine 60 minutes before exercise. Interestingly, usage of caffeinated chewing gum 15 minutes before exercise in dose of 5.4mg/kg proved to be unsuccessful in improving scores in SJFT by elite judo athletes of Polish National Team. Similar conclusion was presented in different paper by Athayde et al. (2019) as intake of 5mg/kg of caffeine by judoists did not affect ratings of perceived exertion, ratings of perceived recovery and other match-derived technical variables[28]. In trained judo athletes ingestion of caffeine in doses of 3 and 6mg/kg enhanced peak bar velocity in the bench press exercise, mean bar velocity in the bench pull exercise and number of repetitions in the dynamic Judogi Grip Strength Test (JGST), exercise similar to classical pull-up exercise. Unfortunately, another paper regarding JGST claimed otherwise, as consumption of 5mg/kg of caffeine by judoists did not improve countermovement jump performance or JGST performance [28].

SJFT was used for testing caffeine not only in judo athletes. It was found that professionals of traditional jiu-jitsu after ingesting 3mg/kg of caffeine achieved better results in number of throws during SJFT. The same dose in different research improved performance of bilateral and unilateral vertical jumps in elite traditional jiu-jitsu athletes[29]. Elite Brazilian jiu-jitsu athletes also seemed to benefit from 3mg/kg dose of caffeine. It helped hand increase grip force in both hands, countermovement jump height. The caffeine also increased the one-repetition maximum and mean power during the bench-press exercise test to failure [30].

Testing dose of 5mg/kg of caffeine in Taekwondo professionals showed its potential in increasing estimated glycolytic energy contribution during simulated combat. However it failed to affect number of attacks, attack time or rating of perceived exertion [31]. Paper describing usage of 200mg independently of body mass also claimed that it did not affect performance during simulated taekwondo combat. At the same time it was found helpful in increasing peak power and mean power per unit of body weight during Wingate Anaerobic Test. Some researchers came to the different conclusions as 5mg/kg dose of caffeine in their trial reduced reaction time in rested athletes and helped to hamper fatigue during consecutive rounds of simulated taekwondo combat [32]. When only female taekwondo athletes were taken into account 3mg/kg caffeine dose together with music of more than 120bpm listened before simulated combat resulted in enhanced number of attacks and defensive actions. Interestingly, decrease of rate of perceived excretion, mean and peak heart rate was also observed in this group. Another study by Ouergui et al. (2023), which enrolled greater population of athletes found out that the dose of 3mg/kg of caffeine regardless of sex improved performance in taekwondo-specific agility test, which includes delivering a single roundhouse kick with the dominant leg to three precisely placed partners. Interestingly adding sets of 10 vertical jumps above 40 cm to work-out protocol can additionally enhance performance in TSAT. Caffeine was also proved useful in hampering decrement of number of kicks using *Bandal Chagui* technique in Multiple Frequency Speed of Kick Test comprising of 5 sets, 10 seconds each[33]

During three round simulated boxing matches ingestion of 6mg/kg of caffeine did not affect heart rate nor rate of perceived exertion[34]. Studying athletes performing Mixed Martial Arts led to similar conclusions as 5mg/kg dose failed to reduce rate of perceived exertion. Punching frequency, mean and maximum punch force were also unaffected. However, in previously mentioned boxers different paper by Coswig et al. (2018) claimed, that caffeine supplementation increased duration of interaction blocks and time in interaction blocks during the first round, but failed to improve total number of actions during entire combat[34]. Another research by Zhang et al. (2024) looked into ingestion of 3mg/kg dose of caffeine by boxers, together with post-activation performance enhancement achieved by comprising a 10 s cycling sprint overloaded with 8.5% of the participants' body weight resulted in increased mean power and total work during Wingate Anaerobic Test. Moreover, self-perceived power was higher in boxers, who consumed caffeine [35].

4. OPTIMAL DOSAGE AND TIMING FOR ATHLETES IN COMBAT SPORTS

Caffeine supplementation has been extensively studied for its ergogenic effects in combat sports, demonstrating a consistent ability to enhance performance across various disciplines and athlete populations. Research indicates that consuming 3–6 mg/kg of caffeine approximately 60 minutes before exercise leads to significant improvements in judo performance. Both doses were similarly effective, suggesting that athletes should prioritize the minimal effective dose (i.e., 3 mg/kg) unless individualized testing shows a preference for higher dosages during simulated competition[36]. Additionally, in traditional jiu-jitsu athletes, an acute caffeine intake of 3 mg/kg improved performance during the Special Judo Fitness Test (SJFT) by increasing heart rate, enhancing strength and endurance perception, and reducing fatigue, although it did not influence the number of offensive or defensive actions during real combat scenarios[37].

In wrestling, a strategy involving moderate doses of caffeine (approximately 6 mg/kg) taken 30–60 minutes before combat, supplemented with smaller doses (~2 mg/kg) during performance, yielded the greatest benefits, particularly for wrestlers experiencing reduced physical performance[38]. Similarly, among Olympic-level boxers, consuming 6 mg/kg of caffeine 60 minutes prior to testing significantly improved anaerobic performance, reaction speed, and neuromuscular efficiency, without altering fatigue levels or electromyographic activity in the lower limbs. In taekwondo, a dose of 5 mg/kg ingested 50 minutes before simulated combat enhanced reaction time and reduced referee stoppages during early rounds, while maintaining combat intensity across successive bouts, suggesting a potential role for caffeine in delaying fatigue during repeated efforts[32].

For Brazilian Jiu-Jitsu (BJJ) athletes, a dose of 3 mg/kg consumed 60 minutes before testing increased maximal isometric and dynamic force production, upper and lower body power output, and muscular endurance. These effects persisted during and after combat, despite similar prevalence of side effects like activeness, muscle soreness, and insomnia compared to a placebo, highlighting caffeine’s safety and efficacy as an ergogenic aid. Another study in judo demonstrated that higher caffeine doses (6–9 mg/kg) were more effective than lower ones (3 mg/kg) in improving performance, particularly in habitual non-consumers of caffeine, where 6 mg/kg was as efficient as 9 mg/kg in enhancing combat activity[25]. In contrast, among habitual consumers, only 9 mg/kg provided superior effects, emphasizing the dose-dependent and individualized nature of caffeine’s ergogenic effects.

Furthermore, a dose of 3 mg/kg was found to increase both the duration and intensity of offensive actions during simulated judo combats, as evidenced by higher lactate levels and perceived fatigue, while also improving specific physical performance tests conducted before competition. However, reductions in grip strength and power in upper limbs after the second combat indicated a high-intensity effort during the trials. Grappling athletes similarly benefited from 5 mg/kg of caffeine, which increased isometric strength and upper-body intermittent strength endurance by 5–7% compared to a placebo[22].

In younger judo athletes, an acute dose of 4 mg/kg improved performance during specific fitness tests, reducing perceived exertion without affecting heart rate, showcasing caffeine's potential in developing athletes. International-level boxers also experienced significant enhancements in anaerobic performance, including peak and average power, after consuming 6 mg/kg of caffeine 60 minutes before testing. These improvements were accompanied by mood-state enhancements such as increased vigor and vitality, particularly in elite athletes[39].

Similarly, amateur boxers consuming the same dose demonstrated increased duration of high-effort punching sequences and decreased pause times during simulated matches, further confirming caffeine's benefits in combat scenarios[34].

The combination of a 3 mg/kg caffeine dose with plyometric warm-up exercises was shown to improve various performance metrics in combat-specific tests, suggesting synergistic effects of caffeine and pre-exercise protocols. Lastly, in judo athletes, the ingestion of 5 mg/kg of caffeine increased plasma fatty acids, lactate levels, and the number of throws during SJFT, while reducing fatigue, particularly in the later stages of randori training. These findings emphasize caffeine's practical applications for improving performance during training sessions that mimic competition[23].

In conclusion, caffeine is an effective ergogenic aid in combat sports, enhancing anaerobic and specific physical performance, delaying fatigue, and improving combat-related activities across various disciplines and athlete populations. Its efficacy is dose-dependent and influenced by individual responses and habitual consumption, with moderate to high doses (5–9 mg/kg) generally providing superior benefits for elite athletes. However, lower doses (3–4 mg/kg) may suffice for some practitioners, offering a balance between performance enhancement and minimal side effects. The optimal timing for caffeine ingestion is 30–60 minutes before exercise, ensuring peak blood concentrations and maximal ergogenic effects.

5. POTENTIAL RISKS AND LIMITATIONS OF CAFFEINE USE

ADVERSE EFFECTS, INCLUDING SLEEP DISRUPTION AND DEPENDENCY.

These are great numer of well-known potential adverse effects, that can have an impact on combat sports athlete performance. Individual differences in caffeine sensitivity are well-documented, with some people being more vulnerable to its anxiogenic effects, as well as sleep disturbances and insomnia[40]. For individuals with anxiety or panic disorders, caffeine can exacerbate symptoms, potentially triggering panic attacks and prompting many to reduce or eliminate caffeine from their diets. In one study, low (3 mg/kg) and moderate (6 mg/kg) caffeine doses resulted in adverse effects for 30% of men and 54% of women. Women were more than three times as likely as men to experience anxiety and nervousness, although over 50% of men and 20% of women reported positive effects from caffeine. These gender disparities may stem from differences in body composition, particularly in fat-free mass.

Previous research has associated caffeine consumption with various adverse effects, such as anxiety, nausea, and vomiting, particularly when consumed in higher doses (6–9 mg/kg)[41]. In contrast, lower doses, such as the 3 mg/kg utilized in one study, have been associated with a reduced frequency of such side effects. Another study noted that athletes commonly reported increased urination, tachycardia, heart palpitations, and anxiety following caffeine intake[42]. These findings are consistent with the CAF-9 trial, where side effects ranged from 0% to 69%, with symptoms such as elevated urination, tachycardia, gastrointestinal discomfort, and heightened vigor being more prevalent in caffeine (CAF) groups compared to placebo (PLAC) groups. Higher doses of caffeine, such as those studied in CAF-11, were linked to an even greater incidence of adverse effects, reaching rates of 0% to 88%. This suggests a dose-dependent relationship between caffeine intake and the occurrence of side effects, a trend corroborated by Pasman et al. (1995), who observed increased adverse effects at doses between 9 and 13 mg/kg[43]. Additionally, individuals who are hypersensitive to caffeine may experience side effects even at relatively low doses. Caffeine, while possessing a low potential for dependence and generally posing minimal risk to individuals or society through the widespread consumption of caffeine-containing beverages, has been shown in studies to induce a clinical dependence syndrome comparable to that caused by other psychoactive substances, underscoring its potential for abuse. Dependence can develop even in adolescents consuming caffeine daily, with symptoms resembling those experienced by adults[44].

The abrupt cessation of regular caffeine intake is well-documented to provoke a cluster of symptoms collectively known as caffeine withdrawal syndrome. Commonly reported symptoms include headache, drowsiness, lethargy, fatigue, reduced work efficiency (manifested as decreased motivation and impaired concentration), a diminished sense of well-being (e.g., lower self-confidence and increased irritability), a drop in blood pressure, and heightened cerebral blood flow. These withdrawal symptoms are in stark contrast to the stimulatory effects typically observed following caffeine consumption
Caffeine intake has also been associated with arrhythmias in humans due to its direct stimulatory effects on myocardial tissue, leading to an increased heart rate and stronger cardiac contractions[45]. The relationship between caffeine consumption and cardiovascular disease (CVD) has been examined through various endpoints, including mortality from myocardial infarction or coronary heart disease (CHD), non-fatal myocardial infarctions,

angina pectoris, and CHD-related hospitalizations. Elevated risks of CVD appear more likely with caffeine intake exceeding five cups of coffee per day (≥500 mg caffeine/day)
Acute caffeine doses (80–250 mg) have been shown to elevate systolic, diastolic, and pulse pressure in both habitual caffeine consumers (following 12–48 hours of abstinence) and non-consumers. Although repeated-dose studies have also noted hypertensive effects, the findings are less consistent compared to single-dose studies[46]. Tolerance to caffeine's hypertensive effects typically develops within 1–3 days in habitual consumers but can reappear after short abstinence periods (e.g., 12 hours). This re-emergence is influenced by factors such as dose, consumption patterns, and individual caffeine metabolism[47].

CONSIDERATIONS FOR BANNED SUBSTANCES IN SPORT.

The source of caffeine administration, such as coffee, energy drinks, or gels, appears to have minimal influence on its ergogenic effects on resistance exercise performance. Several non-genetic factors, however, can influence the rate of caffeine metabolism, primarily through the modulation of cytochrome P450 activity. These factors include smoking, a diet rich in vegetables, pregnancy, training status, and hormone replacement therapy[48]. Moreover, the use of oral contraceptives can prolong caffeine's half-life, resulting in sustained physiological effects. Despite these variations, recent studies suggest that caffeine remains ergogenic throughout all phases of the menstrual cycle[49]. The habitual consumption of caffeine has been hypothesized to diminish its ergogenic potential, although evidence on this matter remains inconclusive. Research by Skinner et al. (2020) highlights that caffeine distribution is largely determined by free body mass, with women generally having a lower proportion of fat-free mass and a higher proportion of body fat compared to men, potentially resulting in higher plasma caffeine concentrations and a greater likelihood of side effects. It is possible that regular caffeine consumers require higher doses to achieve the same performance-enhancing effects. Animal studies have further demonstrated that caffeine supplementation enhances muscle power comparably in both trained mice following an 8-week exercise regimen and untrained control mice[50]. Caffeine metabolism is significantly impaired in individuals with liver diseases, including cirrhosis and hepatitis, as evidenced by reduced plasma clearance, prolonged half-life, and decreased plasma protein binding. These changes reflect the severity of liver dysfunction and are accompanied by delayed synthesis of paraxanthine, a primary caffeine metabolite[51].

Alcohol consumption further affects caffeine metabolism by inhibiting CYP1A2 activity, which significantly prolongs caffeine's half-life and reduces its clearance, although the bioavailability of both substances remains unchanged when consumed together. Notably, caffeine does not mitigate alcohol's detrimental effects on motor or psychological functions, such as impaired driving. However, the expectation of caffeine consumption may partially reduce alcohol-induced performance deficits in certain individuals. Combined binge use of alcohol and caffeine, as seen with energy drinks, has been shown in animal studies to suppress alcohol-induced sedation, resulting in a state of heightened stimulation often referred to as being "wide awake drunk"[52].

Dietary components also modulate caffeine metabolism. Grapefruit juice reduces caffeine clearance by 23% and extends its half-life by 31%, whereas cruciferous vegetables (e.g., broccoli) and high vitamin C intake enhance caffeine clearance. In contrast, apiaceous vegetables and South Asian dietary spices, such as curcumin and turmeric, inhibit CYP1A2 enzyme activity, thereby reducing caffeine metabolism in individuals consuming these foods. Additionally, the flavonoid quercetin alters caffeine metabolism by decreasing urinary excretion of caffeine metabolites, such as paraxanthine, by 32%, highlighting its potential to influence metabolic pathways[53].

CONCLUSION

Caffeine supplementation has demonstrated significant benefits for athletes in combat sports, with improvements in strength, endurance, and performance during high-intensity efforts. The optimal caffeine dose appears to be between 3 and 6 mg/kg, with 60-minute pre-exercise intake providing maximal benefits. Elite athletes may experience enhanced performance with higher doses, but individual variability plays a critical role in determining the most effective dose.

Despite its efficacy as an ergogenic aid, caffeine consumption is not without risks. Adverse effects, such as anxiety, insomnia, tachycardia, and gastrointestinal discomfort, are common, particularly with higher doses. Therefore, athletes should monitor their caffeine intake and adjust the dosage to minimize negative outcomes. Additionally, caffeine's potential for dependence and withdrawal symptoms warrants caution, especially for those who consume it regularly.

Given the widespread use of caffeine in sports, it is essential to consider individual sensitivity, habitual consumption, and other factors such as diet and medication. These variables can influence caffeine metabolism and its effectiveness. The legal status of caffeine in competition remains a key consideration, though it is not banned by most sports organizations. Athletes should remain mindful of their caffeine intake, particularly in relation to performance testing and competition, and consult with healthcare professionals when necessary.

In summary, caffeine is a powerful ergogenic aid in combat sports, but its use should be carefully tailored to the individual athlete. The benefits are clear, but managing risks and side effects will help maximize its performance-enhancing potential without compromising health or compliance with anti-doping regulations.

REFERENCES:

1. Tabben M, Coquart J, Chaabene H, Franchini E, Chamari K, Tourny C. "Validity and Reliability of New Karate-Specific Aerobic Test for Karatekas." *Int J Sports Physiol Perform* 9, no. 6 (Nov 2014): 953-8. https://dx.doi.org/10.1123/ijspp.2013-0465.
2. Ruddock HK, Brunstrom JM, Higgs S. "The Social Facilitation of Eating: Why Does the Mere Presence of Others Cause an Increase in Energy Intake?", *Physiol Behav* 240 (Oct 15 2021): 113539. https://dx.doi.org/10.1016/j.physbeh.2021.113539.
3. Franchini E, Brito CJ, Artioli GG. "Weight Loss in Combat Sports: Physiological, Psychological and Performance Effects." *J Int Soc Sports Nutr* 9, no. 1 (Dec 13 2012): 52. https://dx.doi.org/10.1186/1550-2783-9-52.
4. James P, Hart JE, Banay RF, Laden F. "Exposure to Greenness and Mortality in a Nationwide Prospective Cohort Study of Women." *Environ Health Perspect* 124, no. 9 (Sep 2016): 1344-52. https://dx.doi.org/10.1289/ehp.1510363.
5. Keisler BD, Armsey TD, 2nd. "Caffeine as an Ergogenic Aid." *Curr Sports Med Rep* 5, no. 4 (Jun 2006): 215-9. https://dx.doi.org/10.1097/01.csmr.0000306510.57644.a7.
6. Paluska SA. "Caffeine and Exercise." *Curr Sports Med Rep* 2, no. 4 (Aug 2003): 213-9. https://dx.doi.org/10.1249/00149619-200308000-00008.
7. Nehlig A. "Interindividual Differences in Caffeine Metabolism and Factors Driving Caffeine Consumption." *Pharmacol Rev* 70, no. 2 (Apr 2018): 384-411. https://dx.doi.org/10.1124/pr.117.014407.

8. Jurima M, Inaba T, Kalow W. "Mephenytoin Hydroxylase Activity in Human Liver: Inhibition by Steroids." *Drug Metab Dispos* 13, no. 6 (Nov-Dec 1985): 746-9, https://www.ncbi.nlm.nih.gov/pubmed/2867882.

9. Tian T, Zhang HX, He CP, Fan S, Zhu YL, Qi C, et al. "Surface Functionalized Exosomes as Targeted Drug Delivery Vehicles for Cerebral Ischemia Therapy." *Biomaterials* 150 (Jan 2018): 137-49. https://dx.doi.org/10.1016/j.biomaterials.2017.10.012.

10. Fiani B, Zhu L, Musch BL, Briceno S, Andel R, Sadeq N, et al. "The Neurophysiology of Caffeine as a Central Nervous System Stimulant and the Resultant Effects on Cognitive Function." *Cureus* 13, no. 5 (May 14 2021): e15032. https://dx.doi.org/10.7759/cureus.15032.

11. Daly HE, Czech B, Trauger DL, Rees WE, Grover M, Dobson T, et al. "Are We Consuming Too Much--for What?", *Conserv Biol* 21, no. 5 (Oct 2007): 1359-62; discussion 63-5. https://dx.doi.org/10.1111/j.1523-1739.2007.00770.x.

12. Shen W, Huang B, Yang J. "Ocular Surface Changes in Prostaglandin Analogue-Treated Patients." *J Ophthalmol* 2019 (2019): 9798272. https://dx.doi.org/10.1155/2019/9798272.

13. Volkow ND, Morales M. "The Brain on Drugs: From Reward to Addiction." *Cell* 162, no. 4 (Aug 13 2015): 712-25. https://dx.doi.org/10.1016/j.cell.2015.07.046.

14. Williams DR, Gonzalez HM, Neighbors H, Nesse R, Abelson JM, Sweetman J, et al. "Prevalence and Distribution of Major Depressive Disorder in African Americans, Caribbean Blacks, and Non-Hispanic Whites: Results from the National Survey of American Life." *Arch Gen Psychiatry* 64, no. 3 (Mar 2007): 305-15. https://dx.doi.org/10.1001/archpsyc.64.3.305.

15. Echeverri D, Montes FR, Cabrera M, Galan A, Prieto A. "Caffeine's Vascular Mechanisms of Action." *Int J Vasc Med* 2010 (2010): 834060. https://dx.doi.org/10.1155/2010/834060.

16. Sebastiao AM, Ribeiro JA. "Adenosine Receptors and the Central Nervous System." *Handb Exp Pharmacol*, no. 193 (2009): 471-534. https://dx.doi.org/10.1007/978-3-540-89615-9_16.

17. Neves D, Caldas ED. "Gc-Ms Quantitative Analysis of Black Market Pharmaceutical Products Containing Anabolic Androgenic Steroids Seized by the Brazilian Federal Police." *Forensic Sci Int* 275 (Jun 2017): 272-81. https://dx.doi.org/10.1016/j.forsciint.2017.03.016.

18. Marx W, Manger SH, Blencowe M, Murray G, Ho FY, Lawn S, et al. "Clinical Guidelines for the Use of Lifestyle-Based Mental Health Care in Major Depressive Disorder: World Federation of Societies for Biological Psychiatry (Wfsbp) and Australasian Society of

Lifestyle Medicine (Aslm) Taskforce." *World J Biol Psychiatry* 24, no. 5 (Jun 2023): 333-86. https://dx.doi.org/10.1080/15622975.2022.2112074.

19. Tarnopolsky MA. "Sex Differences in Exercise Metabolism and the Role of 17-Beta Estradiol." *Med Sci Sports Exerc* 40, no. 4 (Apr 2008): 648-54. https://dx.doi.org/10.1249/MSS.0b013e31816212ff.

20. Mohr FW, Falk V, Diegeler A, Walther T, van Son JA, Autschbach R. "Minimally Invasive Port-Access Mitral Valve Surgery." *J Thorac Cardiovasc Surg* 115, no. 3 (Mar 1998): 567-74; discussion 74-6. https://dx.doi.org/10.1016/S0022-5223(98)70320-4.

21. Bazzucchi I, Felici F, Montini M, Figura F, Sacchetti M. "Caffeine Improves Neuromuscular Function During Maximal Dynamic Exercise." *Muscle Nerve* 43, no. 6 (Jun 2011): 839-44. https://dx.doi.org/10.1002/mus.21995.

22. Lopes-Silva JP, Rocha A, Rocha JCC, Silva V, Correia-Oliveira CR. "Caffeine Ingestion Increases the Upper-Body Intermittent Dynamic Strength Endurance Performance of Combat Sports Athletes." *Eur J Sport Sci* 22, no. 2 (Feb 2022): 227-36. https://dx.doi.org/10.1080/17461391.2021.1874058.

23. Carmo KEO, Perez DIV, Valido CN, Dos Santos JL, Miarka B, Mendes-Netto RS, et al. "Caffeine Improves Biochemical and Specific Performance after Judo Training: A Double-Blind Crossover Study in a Real Judo Training Situation." *Nutr Metab (Lond)* 18, no. 1 (Jan 23 2021): 15. https://dx.doi.org/10.1186/s12986-021-00544-5.

24. Astley C, Souza D, Polito M. "Acute Caffeine Ingestion on Performance in Young Judo Athletes." *Pediatr Exerc Sci* 29, no. 3 (Aug 2017): 336-40. https://dx.doi.org/10.1123/pes.2016-0218.

25. Durkalec-Michalski K, Nowaczyk PM, Glowka N, Grygiel A. "Dose-Dependent Effect of Caffeine Supplementation on Judo-Specific Performance and Training Activity: A Randomized Placebo-Controlled Crossover Trial." *J Int Soc Sports Nutr* 16, no. 1 (Sep 5 2019): 38. https://dx.doi.org/10.1186/s12970-019-0305-8.

26. Felippe LC, Lopes-Silva JP, Bertuzzi R, McGinley C, Lima-Silva AE. "Separate and Combined Effects of Caffeine and Sodium-Bicarbonate Intake on Judo Performance." *Int J Sports Physiol Perform* 11, no. 2 (Mar 2016): 221-6. https://dx.doi.org/10.1123/ijspp.2015-0020.

27. Rezaei S, Akbari K, Gahreman DE, Sarshin A, Tabben M, Kaviani M, et al. "Caffeine and Sodium Bicarbonate Supplementation Alone or Together Improve Karate Performance."

J Int Soc Sports Nutr 16, no. 1 (Oct 17 2019): 44. https://dx.doi.org/10.1186/s12970-019-0313-8.
28. Saldanha da Silva Athayde M, Kons RL, Detanico D. "An Exploratory Double-Blind Study of Caffeine Effects on Performance and Perceived Exertion in Judo." *Percept Mot Skills* 126, no. 3 (Jun 2019): 515-29. https://dx.doi.org/10.1177/0031512519826726.
29. Merino Fernandez M, Ruiz-Moreno C, Giraldez-Costas V, Gonzalez-Millan C, Matos-Duarte M, Gutierrez-Hellin J, et al. "Caffeine Doses of 3 Mg/Kg Increase Unilateral and Bilateral Vertical Jump Outcomes in Elite Traditional Jiu-Jitsu Athletes." *Nutrients* 13, no. 5 (May 18 2021). https://dx.doi.org/10.3390/nu13051705.
30. Diaz-Lara FJ, Del Coso J, Garcia JM, Portillo LJ, Areces F, Abian-Vicen J. "Caffeine Improves Muscular Performance in Elite Brazilian Jiu-Jitsu Athletes." *Eur J Sport Sci* 16, no. 8 (Nov 2016): 1079-86. https://dx.doi.org/10.1080/17461391.2016.1143036.
31. Lopes-Silva JP, Silva Santos JF, Branco BH, Abad CC, Oliveira LF, Loturco I, et al. "Caffeine Ingestion Increases Estimated Glycolytic Metabolism During Taekwondo Combat Simulation but Does Not Improve Performance or Parasympathetic Reactivation." *PLoS One* 10, no. 11 (2015): e0142078. https://dx.doi.org/10.1371/journal.pone.0142078.
32. Santos VG, Santos VR, Felippe LJ, Almeida JW, Jr., Bertuzzi R, Kiss MA, et al. "Caffeine Reduces Reaction Time and Improves Performance in Simulated-Contest of Taekwondo." *Nutrients* 6, no. 2 (Feb 10 2014): 637-49. https://dx.doi.org/10.3390/nu6020637.
33. Ouergui I, Mahdi N, Delleli S, Messaoudi H, Chtourou H, Sahnoun Z, et al. "Acute Effects of Low Dose of Caffeine Ingestion Combined with Conditioning Activity on Psychological and Physical Performances of Male and Female Taekwondo Athletes." *Nutrients* 14, no. 3 (Jan 28 2022). https://dx.doi.org/10.3390/nu14030571.
34. Coswig VS, Gentil P, Irigon F, Del Vecchio FB. "Caffeine Ingestion Changes Time-Motion and Technical-Tactical Aspects in Simulated Boxing Matches: A Randomized Double-Blind Pla-Controlled Crossover Study." *Eur J Sport Sci* 18, no. 7 (Aug 2018): 975-83. https://dx.doi.org/10.1080/17461391.2018.1465599.
35. Zhang Y, Diao P, Wang J, Li S, Fan Q, Han Y, et al. "The Effect of Post-Activation Potentiation Enhancement Alone or in Combination with Caffeine on Anaerobic Performance in Boxers: A Double-Blind, Randomized Crossover Study." *Nutrients* 16, no. 2 (Jan 11 2024). https://dx.doi.org/10.3390/nu16020235.
36. Krawczyk R, Krzysztofik M, Kostrzewa M, Komarek Z, Wilk M, Del Coso J, et al. "Preliminary Research Towards Acute Effects of Different Doses of Caffeine on Strength-

Power Performance in Highly Trained Judo Athletes." *Int J Environ Res Public Health* 19, no. 5 (Mar 1 2022). https://dx.doi.org/10.3390/ijerph19052868.
37. Merino-Fernandez M, Giraldez-Costas V, Gonzalez-Garcia J, Gutierrez-Hellin J, Gonzalez-Millan C, Matos-Duarte M, et al. "Effects of 3 Mg/Kg Body Mass of Caffeine on the Performance of Jiu-Jitsu Elite Athletes." *Nutrients* 14, no. 3 (Feb 5 2022). https://dx.doi.org/10.3390/nu14030675.
38. Negaresh R, Del Coso J, Mokhtarzade M, Lima-Silva AE, Baker JS, Willems MET, et al. "Effects of Different Dosages of Caffeine Administration on Wrestling Performance During a Simulated Tournament." *Eur J Sport Sci* 19, no. 4 (May 2019): 499-507. https://dx.doi.org/10.1080/17461391.2018.1534990.
39. Jodra P, Lago-Rodriguez A, Sanchez-Oliver AJ, Lopez-Samanes A, Perez-Lopez A, Veiga-Herreros P, et al. "Effects of Caffeine Supplementation on Physical Performance and Mood Dimensions in Elite and Trained-Recreational Athletes." *J Int Soc Sports Nutr* 17, no. 1 (Jan 3 2020): 2. https://dx.doi.org/10.1186/s12970-019-0332-5.
40. Bchir F, Dogui M, Ben Fradj R, Arnaud MJ, Saguem S. "Differences in Pharmacokinetic and Electroencephalographic Responses to Caffeine in Sleep-Sensitive and Non-Sensitive Subjects." *C R Biol* 329, no. 7 (Jul 2006): 512-9. https://dx.doi.org/10.1016/j.crvi.2006.01.006.
41. Lara B, Gonzalez-Millan C, Salinero JJ, Abian-Vicen J, Areces F, Barbero-Alvarez JC, et al. "Caffeine-Containing Energy Drink Improves Physical Performance in Female Soccer Players." *Amino Acids* 46, no. 5 (May 2014): 1385-92. https://dx.doi.org/10.1007/s00726-014-1709-z.
42. Salinero JJ, Lara B, Abian-Vicen J, Gonzalez-Millan C, Areces F, Gallo-Salazar C, et al. "The Use of Energy Drinks in Sport: Perceived Ergogenicity and Side Effects in Male and Female Athletes." *Br J Nutr* 112, no. 9 (Nov 14 2014): 1494-502. https://dx.doi.org/10.1017/S0007114514002189.
43. Pasman WJ, van Baak MA, Jeukendrup AE, de Haan A. "The Effect of Different Dosages of Caffeine on Endurance Performance Time." *Int J Sports Med* 16, no. 4 (May 1995): 225-30. https://dx.doi.org/10.1055/s-2007-972996.
44. Oberstar JV, Bernstein GA, Thuras PD. "Caffeine Use and Dependence in Adolescents: One-Year Follow-Up." *J Child Adolesc Psychopharmacol* 12, no. 2 (Summer 2002): 127-35. https://dx.doi.org/10.1089/104454602760219162.

45. Mehta A, Jain AC, Mehta MC, Billie M. "Caffeine and Cardiac Arrhythmias. An Experimental Study in Dogs with Review of Literature." *Acta Cardiol* 52, no. 3 (1997): 273-83, https://www.ncbi.nlm.nih.gov/pubmed/9217918.

46. Dobmeyer DJ, Stine RA, Leier CV, Greenberg R, Schaal SF. "The Arrhythmogenic Effects of Caffeine in Human Beings." *N Engl J Med* 308, no. 14 (Apr 7 1983): 814-6. https://dx.doi.org/10.1056/NEJM198304073081405.

47. Shi J, Benowitz NL, Denaro CP, Sheiner LB. "Pharmacokinetic-Pharmacodynamic Modeling of Caffeine: Tolerance to Pressor Effects." *Clin Pharmacol Ther* 53, no. 1 (Jan 1993): 6-14. https://dx.doi.org/10.1038/clpt.1993.3.

48. Pollock BG, Wylie M, Stack JA, Sorisio DA, Thompson DS, Kirshner MA, et al. "Inhibition of Caffeine Metabolism by Estrogen Replacement Therapy in Postmenopausal Women." *J Clin Pharmacol* 39, no. 9 (Sep 1999): 936-40. https://dx.doi.org/10.1177/00912709922008560.

49. Giraldez-Costas V, Del Coso J, Manas A, Salinero JJ. "The Long Way to Establish the Ergogenic Effect of Caffeine on Strength Performance: An Overview Review." *Nutrients* 15, no. 5 (Feb 27 2023). https://dx.doi.org/10.3390/nu15051178.

50. McLellan TM, Caldwell JA, Lieberman HR. "A Review of Caffeine's Effects on Cognitive, Physical and Occupational Performance." *Neurosci Biobehav Rev* 71 (Dec 2016): 294-312. https://dx.doi.org/10.1016/j.neubiorev.2016.09.001.

51. Park GJ, Katelaris PH, Jones DB, Seow F, Le Couteur DG, Ngu MC. "Validity of the 13c-Caffeine Breath Test as a Noninvasive, Quantitative Test of Liver Function." *Hepatology* 38, no. 5 (Nov 2003): 1227-36. https://dx.doi.org/10.1053/jhep.2003.50475.

52. Heinz AJ, de Wit H, Lilje TC, Kassel JD. "The Combined Effects of Alcohol, Caffeine, and Expectancies on Subjective Experience, Impulsivity, and Risk-Taking." *Exp Clin Psychopharmacol* 21, no. 3 (Jun 2013): 222-34. https://dx.doi.org/10.1037/a0032337.

53. Chen Y, Xiao P, Ou-Yang DS, Fan L, Guo D, Wang YN, et al. "Simultaneous Action of the Flavonoid Quercetin on Cytochrome P450 (Cyp) 1a2, Cyp2a6, N-Acetyltransferase and Xanthine Oxidase Activity in Healthy Volunteers." *Clin Exp Pharmacol Physiol* 36, no. 8 (Aug 2009): 828-33. https://dx.doi.org/10.1111/j.1440-1681.2009.05158.x.