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Does caffeine have an impact on endurance, strength or team sport performance? A Systematic Review of the recent findings

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Abstract

Background: Caffeine is one of the most popular and widely consumed stimulants. Its impact on various sports disciplines and types of exercise has been widely examined. However, its influence varies depending on the dosage and athletic discipline. This systematic review examines studies published recently (2020-2025), which assess the impact of caffeine on team sports and endurance-based sports.

Aim: This study aims to present current knowledge regarding the role of caffeine on athletic performance in various sports disciplines.

Materials and Methods: This review followed the PRISMA guidelines. The PubMed database was the main source of examined studies, where a structured search was conducted with strict criteria being: published year 2020-2025, well-trained athletes, and caffeine administered orally. The primary number of research results was 114; 73 were removed in the initial evaluation. Ultimately, after full-text analysis, 19 articles were included in this review.

Results: Across 19 studies, caffeine doses ranged from 2 to 9 mg per kilogram or 160–

250 mg in fixed-dose beverages. Mostly caffeine was administered 60 minutes before the examination. Endurance-based sports seem to benefit the most, which results in increased time to exhaustion, faster time on measured distances, and increased VO_2 max. Team sports benefit from caffeine in better attack accuracy and improved jump height. The results presented in resistance and strength-based sports were inconsistent and were overall task and dosage-dependent.

Conclusions: Caffeine can be an effective and beneficial aid, especially in endurance-based sports, where results were the most promising. Although its positive effect was also documented in basketball and volleyball's jumping exercises. Evidence presented in the resistance and strength-based studies is not consistent enough to recommend caffeine as a reliable performance aid and more research is needed in this area.

Key words: caffeine, energy drink, athletic performance, endurance, strength

Introduction:

Caffeine is one of the most popular and widespread stimulants consumed by millions every day around the world. It can be found in various forms, not only as an ordinary coffee but also as an energy drink, capsule, shot, or gum and when consumed regularly, it has a wide range of positive impacts on the human body (Fiani B. et al., 2021, Evans J. et al., 2020). Various types of energy drinks possessing numerous effects are currently advertised and can be considered a perfect drink before a training or competition. Such drinks often contain not only caffeine but also additions such as sugar, taurine, guarana, ginseng, and group B vitamins (Wassef B, et al., 2017). Although the main focus of this review is on caffeine, it's worth mentioning that other substances have alleged energy and endurance effects. That is why they are sometimes advertised as sports drinks (Wassef B, et al., 2017). Doses of caffeine in such drinks vary between 50-300 mg, where 200 mg is considered safe in a single dose (~3 mg/kg for a 70-kg adult) (EFSA, 2015). Three main mechanisms can explain the cellular effect of caffeine on the human body (Soós R. et al., 2021).

Firstly, it is possible for caffeine to function as an antagonist of the adenosine receptor due to its structural similarity to adenosine, which is a methylxanthine (Abalo R. et al., 2021). Mostly receptors A1 and A2A, but also A2B and A3 (Soós R. et al., 2021). By inhibiting adenosine in the brain and other cells, caffeine mitigates its adverse effects, including fatigue, drowsiness, and diminished vigilance. This enables athletes who consume caffeine to maintain a higher level of power or a longer duration of endurance (Evans J. et al., 2020). Additionally, blocking A1-receptors in cardiomyocytes promotes positive inotropy, so that the force of contraction increases (Soós R. et al., 2021). Indirectly, caffeine also stimulates the release of catecholamines like adrenaline or dopamine, which can contribute to mood and motivation improvement, faster reaction time and muscle motor control, which can widely benefit sports performance (Abalo R. et al., 2021). Furthermore, its overall effect on the central nervous system results in higher free fatty acids and glycerol availability during endurance exercise (Spriet LL., 2013).

Secondly, at higher concentration levels, another mechanism is presented, phosphodiesterase (PDE) inhibition, which causes increased levels of cyclic AMP (cAMP). The higher cAMP in the cells, the more effective lipolysis, thermogenesis and cellular metabolic activity (Abalo R. et al., 2021).

Thirdly, caffeine is able to increase intracellular calcium levels by sensitizing ryanodine receptors which release calcium ions into the cytosol resulting in improved skeletal muscle contractility (Evans J. et al., 2020). Additionally, caffeine may also interact with other neurotransmitter systems (GABA, ryanodine receptors), which may contribute to its complex effects on alertness and mood (Abalo R. et al., 2021). These mechanisms are essential to understanding why caffeine can have such a positive impact on athletic performance.

This review will focus on the effects of caffeine, in its many forms, on athletic performance in three different types of athletic activity: endurance-based sports, team sports, and resistance and strength-based sports, based on the current research available.

2. Research materials and methods

2.1 Data collection and analysis

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline was followed to identify the studies suitable for this systematic review. Meta-analyses and systematic reviews were excluded from this review. The database used was mostly PubMed, with keywords: "((caffeine OR "caffeinated gum" OR "caffeine beverage" OR "caffeine supplementation" OR "energy drink" OR "energy drinks" OR "1,3,7 trimethylxanthine" OR "energy beverage" OR "energy beverages" OR "caffeine drink" OR "caffeine drinks" OR "caffeine beverages") AND (resistance OR "resistance training" OR strength OR power OR "sport" OR "athletic performance" OR "athletic performances" OR jump OR "sport performance" OR "sport performances" OR "team sports" OR "exercise" OR "exercises" OR "physical exercise" OR "physical exercises" OR "aerobic exercises" OR "aerobic exercise")". The articles that were considered are dated between 2020 and 2025. Only well-trained athletes, whose performance was measured after caffeine ingestion in the form of a drink, pill, or gum were considered. All mouth rinses and substances similar to caffeine were excluded from this review. Specific types of exercises were targeted, with the main interest being endurance-based sports, team sports and resistance training. Studies which did not specify the exact type of base or focused on the genetic perspective of caffeine and movement were accordingly removed. During the search, 114 studies were found, and 73 were primarily eliminated. Throughout the assessment, another 22 articles were disqualified due to discrepancies in the researched topics and this review's assumptions. Ultimately, nineteen suitable studies were incorporated into this review.

3. Research results

3.1. Description of studies

Across 19 controlled trials investigating caffeine's ergogenic effects, a total of 336 participants (primarily well-trained young adults) were studied. Participant ages ranged from 16 to 39 years. Caffeine doses varied widely from 2 mg/kg to 9 mg/kg, with several studies using fixed doses of 160–250 mg through energy drinks or pre-workout formulas. The predominant time between caffeine ingestion and exercise was 60 minutes, except in chewing-gum studies, where absorption is rapid (5–15 minutes). The form of caffeine differed by study: capsules (most common), coffee, energy drinks, chewing gum, and multi-ingredient pre-workout supplements. In 18 out of 19 trials, participants answered a questionnaire about their caffeine habituation. Most of the papers studied moderate caffeine consumers, although definitions varied between studies. All studies considered the caffeine washout period to be between 24 hours and 7 days.

Sports disciplines represented in the studies included: cycling, running, CrossFit, volleyball, soccer, basketball, resistance training, anaerobic cycling, and jumping/strength tests. The dataset covers both endurance-based and strength-oriented activities, as well as one post-exercise recovery study.

3.2 Endurance-based sports

Trujillo-Colmena et al. studied 11 recreational cross-country cyclists, who were given 3 mg/kg of caffeine vs. placebo 60 min pre-trial. Their main result was a 4.9% faster time to complete a 13.9 km cross-country course with caffeine in comparison to the placebo group. The maximum speed was also significantly higher under caffeine on average, ranging from 1.8 to 2.0 km/h (Trujillo-Colmena et al., 2024). Pereira JC et al. also report significant improvement of endurance after caffeine. Their study focused on 12 male cyclists divided into three groups: a group with carbohydrates and caffeine (ED1), a group without carbohydrates (ED0), and a decaffeinated placebo (PL). The dose of caffeine was 2 mg/kg. The participants completed a 6 km time-trial, which was preceded by 60 minutes of continuous cycling at 65–75% VO_2max. ED1 and ED0 resulted in a notably shorter time to complete the 6 km trial compared to PL (Pereira JC et al., 2022). The third study, made by Loureiro et. al., focused on whether caffeine intake can enhance muscle glycogen resynthesis during the early recovery period. Fourteen endurance trained adult men, mostly cyclists, participated in the trial, which resulted in significantly greater glycogen recovery after caffeine consumption, roughly 153% greater over 4 h compared with the control group (Loureiro et al., 2021).

Three additional studies focused on caffeine intake among runners. The Reis et al. trial included 12 trained runners who were randomly assigned to one of three groups: conventional ED, which contained caffeine and carbohydrates; sugar-free ED; or placebo. The caffeine dosage was 3 mg/kg. The runners would consume the drinks 40 minutes prior to a strict running protocol in which they would run until exhaustion or until maintaining a sprint as long as possible at a velocity corresponding to 100% of their VO_2 max. Both study groups' performances were significantly better, resulting in reduced perceived effort and improved sprint performance to exhaustion at a rate corresponding to 100% VO_2max (Reis et al., 2020). Stadheim et al.'s research also proved increased time to exhaustion after caffeine ingestion of 4.5 mg/kg. Moreover, their results also showed increased VO_2max in the study group (Stadheim et al., 2021). Bäcker and Jaitner, similar to two prior trials, proved a small (1%) but significant effect in longer running time after consumption of 2 mg/kg of caffeine in the form of an energy drink, 60 minutes before the trial (Bäcker and Jaitner, 2023).

3.3 Team Sports

For the team sports section, seven studies that fulfilled the criteria were selected. Three of them concern volleyball, two focus on soccer, and two on basketball. Nemati et al., who examined volleyball players, reported improvement regarding lower-body power movements, e.g., jumping and change-of-direction abilities, after consumption of 3 mg/kg of caffeine one hour before the trial. Volleyball-specific skills like attack and serve also improved after energy drink intake (Nemati et al., 2023). Kaszuba et al. proved that caffeine dose of 3.2 ± 0.4 mg/kg, via chewing gum, can also improve attack accuracy in male volleyball players. However, it didn't have any significant effects on jump heights, sprint times, agility, serve accuracy, or the other physical tests (Kaszuba et al., 2022). Whereas higher subsequent countermovement jump heights after caffeinated chewing gum were documented in the study made by Filip-Stachnik et al. In the study, female volleyball players were given chewing gum with a higher caffeine dose of 6 mg/kg, which resulted in improved attack jump height. Nevertheless, caffeine did not change game notational performance (points, errors). The authors suggest that caffeine intake alone did not affect jump height (Filip-Stachnik et al., 2022).

Yildirim et al. also used caffeinated chewing gum in the doses of 100 and 200 mg to check if it can significantly enhance quadriceps strength in trained male soccer players. They observed 8–9% improvement in quadriceps strength, whereas there was no effect on vertical jump or ball-kicking speed vs. placebo (Yildirim et al., 2023). Jafari et al. trial assessed the effect of caffeine ingestion of 2 mg/kg on decision-making and pass accuracy in 12 young soccer players. Despite the absence of statistically significant differences, caffeine appears to impair the decision-making abilities of young soccer players. Long pass performance varied with participants' caffeine intake, although short pass accuracy remained consistent. The lower caffeine doses may have a detrimental impact on more intricate tasks with more passes (Jafari et al., 2024).

Still, a study made by Douligeris et al. concerning basketball, proposes that the consumption of 200 mg of caffeine, 30 minutes before training or a match, could considerably improve jumping and agility alactic performance (Douligeris et al., 2023). Also, Nieto-Acevedo et al. conducted a trial on 12 female basketball players, who, after ingestion of 3 mg/kg of caffeine, proceeded to jump and simulated game tests. Outcomes of the experiments show, similarly to Douligeris et al., that caffeine can result in better performance in vertical jump height. The authors observed positive outcomes of change-of-direction speed and number of high-intensity directional changes during a simulated game too (Nieto-Acevedo et al., 2025).

3.4 Resistance and strength-based sports

Out of the 19 studies included in the review, six of them examine resistance and strength-based sports. Grgic et al. examined 25 resistance-trained men, who were given oral caffeine (6 mg/kg). Then they measured bench press repetition velocity across loads, which was significantly improved in comparison to the control group (Grgic et al. 2020). A study conducted by Filip-Stachnik et al. tested the caffeine effect on the number of repetitions and muscle damage following a full-body resistance exercise session. Their trial demonstrated no enhancement in the number of repetitions after 3 mg/kg caffeine ingestion (Filip-Stachnik et al., 2023).

Główka et al. (2024) examined the dose-dependent effects of caffeine supplementation (3, 6, and 9 mg/kg) using the standardized Fight Gone Bad (FGB) CrossFit benchmark protocol on performance, reaction time, and postural stability. While some performance parameters did not reach statistical significance, all caffeine doses resulted in significantly higher lactate concentrations compared to placebo ($p < 0.05$). The 6 mg/kg dose showed clinically noticeable improvements in performance, suggesting that from a practical and athletic standpoint, this dose may be the most effective for CrossFit practitioners (Główka et al., 2024).

A comparative study conducted by Karayigit et al. demonstrated that lower doses of caffeine (3 mg/kg) do not influence upper body strength and muscular endurance performance (Karayigit et al., 2023). Another study made by Burke et al. on female athletes' jumping performance on a 6 mg/kg caffeine dosage showed only a small significant effect, without any concerning strength (Burke et al., 2021). Only Jones et al. trial, with 3 or 6 mg per kilogram, showed a significantly improved muscular endurance in strength-trained females; however, muscular strength was not noticeably increased (Jones et al., 2021).

4. Discussion

Six studies regarding endurance-based sports showed positive outcomes. Both Trujillo-Colmena et al. and Pereira JC et al. reported significantly shorter times to complete trial distances (Trujillo-Colmena et al., 2024; Pereira JC et al., 2022). The authors suggest caffeine likely drives the effect, but additional ingredients (e.g., carbs, taurine) could add synergy; they also note that further research is needed to isolate which components are most ergogenic

(Pereira JC et al., 2022). Another study made by Loureiro et al. proved the notable enhancement in muscle glycogen resynthesis. This could be particularly relevant in contexts where athletes need rapid recovery (Loureiro et al., 2021). Studies examining runners showed an improved performance to exhaustion. Moreover, Reis et al.'s study showed reduced perceived effort, whereas Stadheim et al. identified increased VO_2max in the study group (Reis et al., 2020; Stadheim et al., 2021). The authors propose that the ergogenic effect is likely due to caffeine blocking adenosine receptors, which leads to higher power levels (Reis et al., 2020; Evans et al., 2020). Bäcker and Jaitner, similar to two prior trials, proved significantly longer running times. However, the small effect (1%) and lower caffeine dose in comparison to other studies limit generalizability. The study used a treadmill incremental test rather than a real-world time trial; thus, the applicability to activities such as marathons or long-distance cycling remains uncertain (Bäcker and Jaitner, 2023). Overall, caffeine may significantly influence high-intensity endurance performance when ingested before activity. Depending on the dosage, it can extend the duration until exhaustion and diminish perceived exertion.

Seven articles concerning team sports were considered. Both Nemati et al. and Kaszuba et al. proved that caffeine intake improves volleyball-specific skills like attack accuracy; however, these studies differ when it comes to effects on jump heights and power movement results (Nemati et al., 2023; Kaszuba et al., 2022; Nieto-Acevedo et al., 2025). While Nemati et al. observed advancement in those areas, similarly to the Filip-Stachnik et al. and Douligeris et al. trials, Kaszuba et al.'s outcomes did not show it (Nemati et al., 2023; Kaszuba et al., 2022; Filip-Stachnik et al., 2022; Douligeris et al., 2023). It is suggested that attack accuracy may be due to increased neuromuscular activation and central nervous system stimulation. However, agility increased significantly only after 6 mg/kg of caffeine, proposing that dosage plays an important role in the effects (Nemati et al., 2023). Yildirim et al. observed 8–9% improvement in quadriceps strength, whereas there was no effect on vertical jump or ball-kicking speed vs. placebo (Yildirim et al., 2023). Another trial conducted on soccer players made by Jafari et al. showed impairment of decision-making capabilities, no difference regarding short pass performance between the study group and placebo, and better outcomes of long pass execution. Although the differences were not statistically significant (Jafari et al., 2024). In conclusion, there is evidence proving that caffeine can support team-sport athletes, especially in terms of attack and serve accuracy in volleyball, whereas its effects on soccer performance are not evident. Positive outcomes were registered concerning jump heights in both basketball-focused trials. Even though doses in the experiments were different, both findings suggest enhancement in physical performance in basketball. In comparison to caffeine capsules or energy drinks, the advantages of caffeinated chewing gum appear to be negligible from a practical perspective, at least for athletes who are accustomed to caffeine consumption (Kaszuba et al., 2022).

Six studies concerning resistance and strength types of sports were included in the review. The results regarding caffeine's effects on resistance and strength-based performance were mixed and appeared to be both dose- and task-dependent. The trials examined exercises like bench press repetition velocity, full-body training, CrossFit protocols, and leg press machine exercises and jump trials (Grgic et al. 2020; Główka et al., 2024; Jones et al., 2021; Karayigit et al., 2023; Burke et al., 2021). It was implied that isolated placebo ingestion may not be ergogenic for mean repetition velocity in resistance exercise, as there were no evident differences between the placebo and control conditions. The enhancements in performance after caffeine consumption can primarily be attributed to caffeine's physiological mechanisms of action (Grgic et al. 2020). Caffeine may also offer benefits in reducing oxidative stress following a resistance training session. Further experiments should examine whether the reduction of oxidative stress by caffeine mitigates certain training adaptations elicited by resistance exercise (Filip-Stachnik et al., 2023).

Główka et al.'s study on the Fight Gone Bad CrossFit protocol demonstrated that while not all performance metrics reached statistical significance, physiological markers (lactate concentrations) were significantly elevated across all caffeine doses compared to placebo. The medium dose of caffeine (6 mg/kg) induced clinically noticeable improvements, which implies that, from the practical and athletic standpoint, this dose may be the most effective for CrossFit practitioners (Główka et al., 2024).

Overall, the evidence suggests that caffeine's effects on resistance and strength-based exercises are complex and context-dependent. The outcomes differ depending on dosage, exercise type, and measured parameters. Only one out of all the included articles in this section (Jones et al., 2021) showed increased ability for higher workload training in terms of muscular endurance, though not maximal strength.

5. Conclusion

The main benefit of caffeine appears to be consistently seen in endurance-based sports in most of the researched exercises. These effects demonstrated themselves at doses between 2 and 6 mg/kg, ingested 60 minutes before the planned activity. Volleyball and basketball performance also seemed to improve, especially in attack accuracy or jump height. However, other components did not show any improved features.

Outcomes in resistance and strength-based sports were inconsistent and task-dependent. While some studies showed improvements in specific parameters such as repetition velocity or muscular endurance, others found no significant effects. Physiological markers like lactate concentration may respond to caffeine even when performance metrics do not reach statistical significance, suggesting that the ergogenic effects of caffeine in strength-based activities may be more nuanced than in endurance sports.

In conclusion, caffeine is a useful enhancer for sports activities, especially endurance-type activities, and should be considered as additional support. For resistance and strength-based sports, more research is needed to establish clear dosage recommendations and identify which specific performance parameters are most likely to benefit from caffeine supplementation.

Disclosure

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