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Caffeine and Cognitive Performance in Healthy Adults: Domain-Specific Effects and Dosing Considerations

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Abstract

Background: *Caffeine is widely consumed for its potential cognitive-enhancing effects, yet findings across cognitive domains and dosing regimens remain heterogeneous.*

Obectives: *This systematic review aimed to evaluate the effects of low (100-200 mg) and high (300-400 mg) doses of caffeine on cognitive performance, specifically attention, memory, and executive function in healthy adults aged 18-60 years, compared to placebo.*

Methods: *We included randomized controlled trials (RCTs) that evaluated the effects of low-dose (100–200 mg) or high-dose (300–400 mg) caffeine on cognitive performance in healthy adults (aged 18–60 years). These studies assessed cognitive domains such as attention, memory, or executive function using standardized cognitive tests. Studies were excluded if they involved pediatric ($<$ 18 years) or elderly populations ($>$ 60 years), individuals with cognitive impairments, or if they assessed non-cognitive outcomes. Databases searched included PubMed, Embase, Scopus, and Web of Science, from 2015 until 2025. Risk of bias in the included studies was assessed using Cochrane Risk-of-Bias (RoB2-tool). Data extraction and analysis were performed using Covidence.*

Results: *Twenty RCTs (n = 951; ages 18–60) were included. Low-to-moderate caffeine doses (100–200 mg) consistently improved sustained attention, vigilance, and reaction time, with stronger effects observed in low habitual consumers. Working memory showed overall improvement, though findings varied by task and baseline caffeine intake. Executive function outcomes were heterogeneous, with task-specific benefits but no consistent pattern. Mood and arousal frequently improved, while higher doses ($\geq$ 300 mg) produced null or inconsistent effects. Importantly, although studies evaluated varying caffeine doses, none directly compared low versus high doses within the same experimental design, precluding firm conclusions regarding dose–response superiority. Risk of bias was mostly moderate, reflecting issues with blinding and outcome reporting.*

Conclusions: *Caffeine appears to exert domain-specific cognitive effects in healthy adults, with more consistent benefits observed in attention-related measures than in executive function. The absence of direct low–high dose comparisons limits conclusions regarding optimal dosing; though trials with low dose seem to produce larger effects. Future trials should directly compare dosing strategies and comprehensively assess multiple cognitive domains to clarify potential tradeoffs between attentional enhancement and executive performance.*

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Introduction

Caffeine is the most consumed psychoactive substance worldwide, with nearly 80% of the world population consuming it (Samoggia & Rezzaghi, 2021). Its habitual use is primarily through coffee, tea, soft drinks, energy beverages, and dietary supplements. Caffeine acts as a nonselective adenosine receptor antagonist, which causes mild dilation of blood vessels and increases blood pressure, metabolic rate, and urine production (Echeverri et al., 2010). Also, caffeine can cross the blood-brain barrier, impacting cognitive state and generating subjective effects, including increased well-being, mental energy, motivation, and self-confidence (Lieberman, 2009).

Caffeine has several potential health effects, from reducing the risk of some cancers (Pauwels & Volterrani, 2021), diabetes (Carlström & Larsson, 2018), neurodegenerative disorders (Y. Chen et al., 2021; Li et al., 2024), and cardiovascular disorders, although the latter with contradictory results (Ding et al., 2014; J. Wu et al., 2009). However, the principal reasons for consumption are increased alertness (Irwin et al., 2020), improved cognitive performance (Quiquempoix et al., 2022), and counteracting fatigue (X. Chen et al., 2020), leading to many groups studying the cognitive effects of coffee. Cognitive domains frequently assessed in this context include attention, memory, and executive functions, critical for daily functioning and overall mental performance (Lorenzo Calvo et al., 2021).

Although numerous studies have explored the relationship between caffeine intake and cognitive outcomes, the existing literature presents heterogeneous findings, influenced by variations in study populations, caffeine dosing, outcome assessment methodologies, and comparator groups. In addition, previous reviews have often included diverse populations such as adolescents, older adults, individuals with cognitive impairments, and athletes, thereby limiting the applicability of their findings to the general healthy adult population. Moreover, the role of dose-dependent effects (low versus high dose) on specific cognitive domains in well-controlled settings is still not sufficiently clarified. Finally, individual factors such as habitual caffeine consumption and genetic polymorphisms may modulate cognitive responses to caffeine, but these factors have not yet been adequately explored in synthetic studies.

Given the high prevalence of caffeine consumption worldwide and its potential relevance to clinical practice and individual health choices, it is imperative to provide an updated synthesis of high-quality evidence focused specifically on healthy adults. This systematic review addresses a key gap in the literature: there are no recent, comprehensive reviews examining the dose-dependent cognitive effects of daily caffeine intake (100–400 mg/daily) in healthy adults aged 18 to 60 years, compared with placebo using validated cognitive tests.

From a clinical perspective, understanding whether specific doses of caffeine improve cognition can inform evidence-based recommendations for individuals seeking safe, non-pharmacological strategies to enhance mental performance.

Materials and Methods

Review process

This review followed a systematic review design based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Page et al., 2021). The study was conducted to identify, appraise, and synthesize evidence from randomized controlled trials (RCTs) evaluating the acute cognitive effects of caffeine in healthy adults. The research protocol included predefined eligibility criteria, search strategies, data extraction procedures, and risk-of-bias assessment. Because of the anticipated heterogeneity in cognitive tasks, doses, and outcome measures across studies, a narrative synthesis was chosen instead of a quantitative meta-analysis. All stages, from study selection to data synthesis, were independently reviewed by at least two authors to ensure transparency and minimize bias.

Eligibility

This review included both parallel and crossover Randomized Controlled Trials (RCTs) that investigated the acute or short-term effects of caffeine administration on cognitive performance in healthy adult participants (aged 18–60 years). Eligible studies specifically assessed the impact of low-dose caffeine (100–200 mg) or high-dose caffeine (300–400 mg) on standardized cognitive function measures, including tests of attention, working memory, executive function, mood and arousal, problem solving, and motor tasks. The cutoffs for low (100–200 mg/day) and high (300–400 mg/day) caffeine intake were established based on international safety and pharmacological guidelines. According to the U.S. Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA), daily caffeine intake up to 400 mg (approximately 5.7 mg/kg for a 70 kg adult) is considered safe for healthy adults, while doses around 100–200 mg correspond to typical single servings such as one to two cups of coffee. These thresholds have been used in previous epidemiological and experimental

studies investigating caffeine's effects on mood and cognition (Temple et al., 2017; Poole et al., 2017). Studies were excluded if they involved pediatric populations (aged < 18 years), older adults (aged > 60 years), individuals with pre-existing cognitive impairments, or athletic populations. Trials examining the effects of other stimulants, such as tea-derived compounds, amphetamines, or modafinil, were excluded. Additionally, only studies employing a placebo-controlled design were considered. Trials evaluating outcomes unrelated to cognitive function, including sleep-related measures or non-cognitive endpoints, were also excluded.

Information sources and search strategy

A comprehensive literature search was conducted across four major biomedical databases: PubMed, Embase, Scopus, and Web of Science. The complete search strategies for all databases are provided in Supplementary Table 1. Boolean operators were employed to identify relevant publications investigating the effects of caffeine consumption on cognitive function. The search was limited to peer-reviewed articles published in English between 2015 and 2025 and was conducted on April 24, 2025. The search strategy was developed using different terms based on the database used, and refined based on our population, intervention, control, and outcomes (PICO) framework. The initial query yielded a total of 2,881 articles. References were imported into the Covidence platform, and duplicated references were automatically removed by searching for simultaneous matches in the author, title, and year fields. One of our team members conducted an additional manual search to identify further duplicates.

Study selection process

Our review adheres to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021), and the selection process is outlined in Figure 1. All studies were exported to the Covidence platform (Systematic review software, Veritas Health Innovation, Melbourne, Australia) which handled searched citations. Duplicates were identified and excluded by Covidence. Then, a manual check was carried out to cross-check for remaining duplicates. All authors participated as first, second, and third reviewers. We retrieved relevant full-text publications, and two review authors independently screened the full texts and recorded reasons for the exclusion of the ineligible studies. A list of studies excluded after full-text screening, along with specific reasons for exclusion, is provided in Supplementary Table 2. The same investigators resolved disagreements through discussion, or, if required, they consulted a third author to reach a consensus.

Data collection process

For the extraction phase, we followed the recommendations outlined in the Cochrane Handbook for Systematic Reviews of Interventions Version 6.5 (updated August 2024) (Higgins et al., 2024). All authors contributed to extract the following information for each trial: year of the study, the first author's name, country of study, study design, total sample size, population characteristics, intervention groups, cognitive tests used as outcome, and main results. Two independent reviewers conducted data extraction using standardized data collection forms within the Covidence platform. Any discrepancies between reviewers were resolved through discussion between both reviewers until consensus was achieved.

Risk of bias assessment

Two authors independently evaluated the methodological quality of the included studies using version 2 of the Cochrane Risk of Bias tool for randomized trials (RoB 2) as recommended in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019). RoB 2 assesses five domains of potential bias known to influence the validity of randomized trial results: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome; and (5) bias in the selection of the reported result. For crossover RCTs, only studies in which the washout period was specified were included. This helps ensure that the effects observed in the current intervention are not influenced by the previous treatment. No studies were excluded based on the results of the quality assessment. Any discrepancies between reviewers were resolved by consensus, and when consensus could not be reached, a third reviewer was consulted.

Data synthesis

All studies that met the eligibility criteria and provided relevant information were included in the synthesis. The extracted data were exported from Covidence into a Microsoft Excel® spreadsheet and descriptively summarized in Table 1. Regarding

effect metrics, means and standard deviations of cognitive test results were extracted, as well as change scores when available. Change scores were calculated by subtracting the mean baseline score from the mean post-intervention score. Due to the heterogeneity in study designs, interventions, and outcomes, a narrative synthesis was conducted to integrate and interpret the findings. This approach was deemed appropriate given the complexity and variability across the included studies. No attempts were made to contact the original authors for additional data; when information was missing from the trials, it was recorded as "NA" (not available).

Results

Description of the studies

Figure 1 shows the results of the systematic search and selection of eligible studies. The literature search yielded a total of 2,881 studies, from which 707 duplicates were removed. After a preliminary screening of titles and abstracts, 2,174 studies were excluded, and 67 full-text studies were reviewed. In total, 20 studies met inclusion criteria as shown in the PRISMA flow diagram (Figure 1). All studies included were randomized controlled trials (RCTs). The key characteristics of each included study are presented in Table 1.

Several studies that initially appeared to meet the inclusion criteria were excluded after full-text review. These exclusions were due to various reasons, including the use of inappropriate study designs, irrelevant interventions, or patient populations not aligned with the review's focus. Some studies were excluded for reporting outcomes or settings that did not match the review objectives, while others were conference abstracts lacking sufficient methodological detail. Additionally, a few studies were excluded due to the use of non-comparable control groups. These decisions were made to ensure the methodological rigor and relevance of the included evidence.

Study characteristics

Population

A total sample of 951 individuals was included in the analyses across 20 RCTs. The mean age of participants ranged from 18 to 60 years, with most samples composed of young to middle-aged adults, particularly individuals in their twenties and thirties. The populations studied were diverse, encompassing healthy adults, university students, physical education students, and healthy postmenopausal women. Most trials enrolled non-smoking participants without psychiatric, neurological, or metabolic disorders, and systematically excluded those with caffeine hypersensitivity, substance use, or the use of interfering medications. Habitual caffeine intake ranged from low (<100 mg/day) to moderate (100–300 mg/day), with several studies explicitly recruiting low habitual consumers to minimize the influence of tolerance-related confounding. The trials were conducted in controlled academic or clinical research settings across a wide range of countries, including the United States, United Kingdom, Italy, Germany, Brazil, Japan, Tunisia, Australia, Switzerland, and the Netherlands, ensuring broad geographical and cultural representation and enhancing the external validity of the findings.

Interventions and control conditions

In the 20 RCTs included in this systematic review, caffeine was administered in various forms, doses, and experimental conditions, all with standardized, blinded, and methodologically rigorous designs. Caffeine doses ranged from 100 to 400 mg, consistent with predefined thresholds for low (100–200 mg) and high (300–400 mg) exposure.

The most common dose across the studies was 200 mg of caffeine (Akyürek et al., 2025; Bloomer et al., 2015; Franceschini et al., 2020; Kassim, 2024; Konishi et al., 2018; Kruger et al., 2024; Zabelina & Silvia, 2020). These studies typically administered caffeine in capsule or gum and assessed a broad range of cognitive domains, including attention, working memory, and executive function. A smaller subset of studies investigated high-dose caffeine administration (300–400 mg) (Lin et al., 2023; Souissi et al., 2019; Waer et al., 2021; Wicht et al., 2022). These studies specifically examined dose–response effects by comparing low and high caffeine conditions.

To preserve double-blind integrity, control interventions were matched to the active treatments in taste, texture, appearance, and administration timing. Placebo strategies included use of decaffeinated coffee (Haskell-Ramsay et al., 2018; Renda et al., 2015), inert capsules (Waer et al., 2021; Zabelina & Silvia, 2020), and flavor-matched non-caffeinated beverages (De Longis et al., 2022; Franceschini et al., 2020).

In psychological expectancy studies, participants were deliberately misinformed about caffeine content of the administered product to isolate and compare pharmacological effects with expectancy-driven influences on cognitive performance (Wicht et al., 2022). In crossover trials, washout periods ranged from 24 hours to 7 days, with most studies implementing a minimum of 48 hours to mitigate

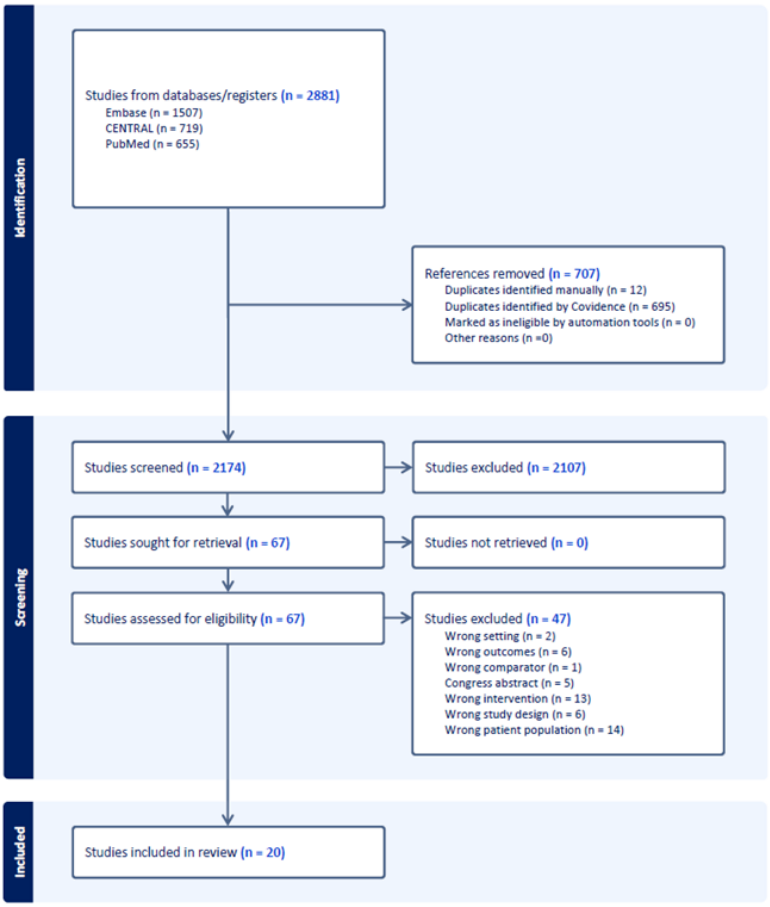

Figure 1: *PRISMA flow diagram.*

Year	Author's name	Sample size (n)	Mean age (years)	Females (%)	Habitual caffeine consumption
2015	Bloomer et al	20	24	0	Regular caffeine consumers (≥2x/week)
2015	Renda et al	106	26	0	Moderate caffeine consumers (1–3 cups/day)
2015	Ullrich et al	17	28.5	0	Not specified
2016	Lanini et al	58	25.2	0	Moderate habitual caffeine intake.
2018	Haskell-Ramsey et al	59	25.3	49	Habitual caffeine consumers (≥150 mg/day)
2018	Konishi et al	100	41	50	Not specified
2019	Souissi et al	15	20	0	Non-users of caffeine
2020	Barry et al	24	21.6	66.6	Moderate caffeine users (2–4 cups of coffee or equivalent daily)
2020	Franceschini et al	First Study: 24 Second study: 53	Not specified	First study: 75.0 Second study: 77.4	Both studies: low-to-normal caffeine consumers
2020	van der Berg et al	31	24	68	Regular coffee drinkers
2020	Zabelina et al	80	Not specified	68.2	Habitual caffeine consumers (1–2 cups/day, 5+ days/week)
2021	Laatar et al	20	52	100	Low habitual consumers of caffeine (109.2 ± 58 mg/day)
2021	Waer et al	19	52	100	Low habitual caffeine intake (<200 mg/day)
2022	DeLongis et al	22	35.3	0	Not specified
2022	Wicht et al	48	24	0	Moderate caffeine drinkers (1 to 4 cups of coffee or 4 energy drinks or 8 cups of tea or 8 cans of soda/day)
2023	Kassim et al	20	22.2	30	Not specified
2023	Lin et al	20	26.4	0	Habitual caffeine intake 474.1 ± 107.5 mg/day
2024	Kassim et al	40	26	27.5	Not specified
2024	Kruger et al	127	20.4	66.1	Not specified
2025	Akyurek et al	48	21.9	50	Not specified

Table 1: *Studies sample characterization.*

Year	Author's name	Country	Study design	Sample size	Population characteristics	Intervention groups	Cognitive tests used to assess outcome	Main results
2015	Bloomer et al	USA	Randomized single-blind, crossover study	20	Healthy young adults aged 18–30 , mostly university students, Regular caffeine consumers (≥2x/week); BMI < 30; normotensive. 75% Caucasian, 20% African American, 5% Middle Eastern. Exclusion criteria: hypertension, obesity, pregnancy, neurological/metabolic/mental disorders, smoking, substance abuse, and interfering medications/supplements.	1. 5-Hour ENERGY (=200 mg caffeine + proprietary blend) 2. Caffeine capsule (200 mg) + placebo drink 3. Placebo drink + placebo capsule Single-dose interventions; 1-week washout between sessions	- Trail Making Test (TMT)- - Digit Symbol Substitution Test (DSST) - Subjective energy scale (10-point rating) Tests evaluating visual attention and executive function	No significant differences between caffeine and placebo for TMT or DSST. Subjective energy was slightly higher for caffeine (not significant).
2015	Renda et al	Italy	Randomized, double-blind, crossover clinical trial	106	Male university students aged 20–38 (mean 26 ± 4); non-smokers, no comorbidities, physically moderate activity, moderate caffeine consumers (1–3 cups/day) Exclusion: drug use, hypertension, BMI <18.5 or >30, and color blindness	Caffeine condition: 3 mg/kg caffeine in decaffeinated coffee Control condition: Decaffeinated coffee only 24h washout period	- Categorical Search Task (attention: alerting/orienting) - Stroop Task (executive control) - Eriksen Flanker Task (executive control)	Caffeine improved attention (faster response times) and executive control across all tasks compared to placebo.
2015	Ullrich et al	Germany	Randomized Crossover double-blinded	17	Healthy, normal weight, males aged 19 - 40 (mean 28.8 ± 4.4)	Caffeine: (decaf + 200 mg of caffeine and artificially sweetened drink) Placebo: (decaf drink + artificially sweetened drink) (washout period- 1 week)	5 cognitive tests 2 hours per session (logical reasoning, speed of information processing, working memory, verbal memory, attention, and ability to concentrate.	Caffeine had no significant effects on cognitive performance compared to placebo.
2016	Lanini et al	Brazil	Randomized Double double-blind, placebo-controlled, factorial, parallel-group design	58	Healthy male, aged 19–35 years (mean: 25.2 ± 4.9), ≥12 years of education, Portuguese speakers, no comorbidities, moderate habitual caffeine intake. Exclusion: Women.	Caffeine Fasting: Personalized caffeine dose (based on habitual intake) in capsule form after overnight fast - Placebo Fasting: Placebo capsule (talc) after fast - Caffeine Meal and Placebo Meal: Same capsule protocol, after a standardized meal	- Random Number Generation (RNG): Updating (executive function) - Psychomotor Vigilance Task (PVT): Sustained attention - Zoo Map Test: Planning (executive function)	Caffeine improved RNG in fed conditions. PVT and Zoo Map results are inconclusive or inconsistently reported.
2018	Haskell-Ramsay et al	UK	Randomized placebo-controlled, double-blind, counterbalanced crossover trial	59	Healthy adults both sexes (51% M, 49%F); mean ages: young = 25.28 ± 3.8; (29 younger adults aged 20–34; 30 older adults aged 61–80), habitual caffeine consumers (≥150 mg/day); Participants with stable chronic conditions (e.g., hypertension, arthritis) were included	1. Regular Coffee (100 mg caffeine) 2. Decaffeinated Coffee (~5 mg caffeine) 3. Placebo (coffee-flavored water) Crossover design with ≥7 days washout period	- Digit Vigilance Accuracy (attention) - Rapid Visual Information Processing (RVIP) (sustained attention) - Simple and Choice Reaction Time (RT) (processing speed)	Caffeine improved attention and reaction time vs. placebo and decaf
2018	Konishi et al	Japan	Randomized Double-blind, placebo-controlled, parallel-group trial	100	Healthy Japanese adults aged 22–59; 50 M and 50 F, Valid driver's licenses, no psychiatric diagnosis, no significant differences between groups in demographics or driving habits	1. Caffeine (200 mg capsule), N=50 2. Placebo (200 mg sugar capsule) N=50 Single oral dose; participants blinded to condition	Symbol Digit Coding (SDC) - Stroop Test (simple/complex/stroop RT) - Shifting Attention Test - Four-Part Continuous Performance Test (Cognitrax)	Only Shifting Attention improved with caffeine No significant effects on other tests.
2019	Souissi et al	Tunisia	Randomized, double-blind, counterbalanced crossover trial	15	Healthy Male students ~20 years old, non-users of tobacco, alcohol, caffeine, antioxidants, or anti-inflammatories	1. Caffeine (6 mg/kg) 2. Placebo Each tested across 6 time points (morning to evening); crossover with ≥3-day washout period	- Simple Reaction Time (RT) - Digit Vigilance Task (sustained attention)	Caffeine improved reaction time and vigilance, especially in morning sessions.
2020	Barry et al	Australia	Randomized double-blind placebo-controlled repeated measures crossover study.	24	Healthy adults (16 F, 8 M), mean age was 21.6 ± 4.7. Self-identified as nonsmokers and moderate caffeine users (2–4 cups of coffee or equivalent daily).	250 mg caffeine Placebo in identical gelatin capsules Washout period- 1 week	1.Auditory Go/NoGo task, in terms of the event-related potential (ERP)	Nonsignificant reductions in RT and Go omission errors, fast RT errors, delayed RT errors, or RT variability. Caffeine can enhance simple RT performance. Moderate doses of caffeine do not have substantial activation effects on behavior in the Go/NoGo task.
2020	Franceschini et al	Italy	A double-blind, repeated measures design was used in two mechanistic studies.	First Study: 24 Second study: 53	First study: 24 volunteers (18 female, 6 male), low-to-normal caffeine consumers Second study: 53 volunteers (41 female, 12 male), low-to-normal caffeine consumers	200 mg caffeine Placebo Both in solution form	First Study: 1. Standardized reading test 2. Word text reading 3. Pseudoword text reading 4. Lexical long-term memory 5. Anxiety evaluation. Second study: 1. Computerized reading tasks. 2. Single-word reading task. 3. Single pseudoword reading task 4. Perceptual Naveon task. 5. Attentional Network Task.	First study: Consumption of a single dose of 200 mg of caffeine significantly improved reading speed Second study: The presence of a beneficial effect of caffeine on word text reading speed was confirmed in the second replication study. Analysis of text reading performance established that after caffeine intake, participants significantly improved their reading speed
2020	van der Berg et al	The Netherlands	Randomized Crossover	31	Healthy adults, 32% male, aged 18-31,Regular coffee drinkers, Regular sleep schedule, Normal or corrected to normal vision, non-smokers.	Caffeine (3 mg/kg) or placebo, with a washout period of 7 days.	Stoop test for executive function Two sessions of the Stroop test after receiving a sign indicating the possibility of a monetary reward	Caffeine intake improved response time and accuracy and facilitated the neural processes of attentional preparation and stimulus processing for task-relevant information.
2020	Zabelina et al	United States	Randomized, placebo-controlled, double-blind, between-subject (parallel design)	80	Adults aged 18–35, habitual caffeine consumers (1–2 cups/day, 5+ days/week), non-smokers, not taking psychiatric medications or painkillers	1. Caffeine group: 200 mg caffeine capsule N=40 2. Placebo group: Identical placebo capsule (sugar), N=40 Single-dose administration	Compound Remote Associates (CRA): convergent thinking - Insight vs. Analytic problem-solving (CRA subcomponents) - Reaction Time (RT) measures mood and expectancy controls	Caffeine improved CRA accuracy and reduced insight R.
2021	Laatar et al	Tunisia	Randomized placebo-controlled, counterbalanced, double blind	20	Healthy middle-aged women (52 ± 2.0 years; height 158 ± 2.BMI ±3.4 kg/m2, mean ± SD), Low habitual consumers of caffeine (109.2 ± 58 mg/day) post-menopause for 4 years. Moderate weekly activity level, no history of cardiovascular, metabolic, renal, hepatic, or musculoskeletal disorders, no use of any medical substances or nicotine or treatments that could mask the effects of caffeine, and no sensitivity to caffeine.	1. Caffeine: Capsule containing 100 mg of caffeine 2. Placebo: 0 mg of caffeine (identical capsule)	Single task: Block 1 postural balance, Block 2 walking trials, Block 3 working memory Dual task: Block 1 Walking and cognitive tasks (number of correct responses) Block 2 standing balance and cognitive tasks (number of correct responses)	Standing and walking dual task performances are improved after caffeine consumption Cognitive performance improved with caffeine No significant difference in motor performance between single and dual tasks after caffeine consumption.
2021	Waer et al	Tunisia	Randomized, double-blind, crossover trial	19	Healthy postmenopausal women aged 40–60 years (mean: 52 ± 3), moderate physical activity, low habitual caffeine intake (<200 mg/day), no comorbidities	1. Low Caffeine: 100 mg 2. High Caffeine: 400 mg 3. Placebo: 0 mg >14-day washout between test conditions	Simple Reaction Time Test	Low dose improved RT; high dose did not differ from placebo.
2022	DeLongis et al	Swiss	Randomized, single-blind, crossover trial	22	Healthy adults (Age 22–48; Mean = 35.3 ± 8.2 years); Non-smokers, no food allergies or neurological conditions	1. CCB: Carbonated caffeinated beverage 2. CB: Non-carbonated caffeinated beverage 3. Control: Placebo (flavor-matched, no caffeine) Washout period: ≥6 days between sessions	-Sustained Attention Task (90 minutes) - Accuracy (hits), Reaction time -Self-reported outcomes: Physical/mental energy and fatigue	CCB and CB improve the performance in Sustained Attention Tasks. Higher levels of physical and mental energy, and lower levels of mental and physical fatigue.
2022	Wicht et al	Swiss	Randomized within-subject, cross-over design	48	Healthy 18-30 years old participants; moderate caffeine drinkers (1 to 4 cups of coffee or 4 energy drinks or 8 cups of tea or 8 cans of sodas/day), non-smokers, no history of substance-abuse, no personal history of diagnosed neurological or psychiatric disorders and of heart and circulatory disease, and regular consumption of less than or equal to 21 units of alcohol/week	Caffeine (240 mg + 120 mg)/45 minutes later (total of 360 mg) Decaffeinated capsules (3–6 mg caffeine) Caffeine vs Decaffeinated capsules 3-6 mg caffeine Washout period- 1 week	- Rapid Visual Information Processing task (RVIP) - Go/NoGo motor inhibitory control task.	RVIP: No performance benefits from caffeine. Global field power stronger values in caffeine population in Attention P3 voltage Go/NoGo: No performance benefits. Higher GNG NoGo P3 component
2023	Kassim et al	Australia Ethiopia	Randomized, double-blind, placebo-controlled, crossover pilot studies	20	Healthy adults, age 18–59, non-pregnant, no psychiatric, neurological, or cardiovascular conditions. Mean age: 22.2 ± 4.1 years; 70% male; Mean weight: 80.3 ± 20.0 kg; Education: 14.6 ± 1.5 years.	Caffeine 200 mg PO versus Placebo (N=20) Design: 2 sessions, 1-week washout period	Spatial Working Memory (SWM): Forward Spatial Span; Backward Spatial Span; Total Spatial Span Score Verbal Working Memory (VWM): Digit Span Task	Improved spatial working memory (Spatial Span Task); No significant effect on verbal working memory Well tolerated, no drop-outs
2023	Lin et al	Swiss	Randomized, double-blind, placebo-controlled crossover trial	20	Healthy male adults, non-smokers, mean age 26.4 ± 4.0 years, habitual caffeine intake 474.1 ± 107.5 mg/day	1. Caffeine (150 mg x3/day) 2. Placebo (mannitol x3/day) 3. Withdrawal (9 days caffeine + 1 day placebo)	0-back test (attention/psychomotor); 2-back (working memory);	3-back RT and accuracy: no significant improvements with caffeine vs placebo. Withdrawal reduced WM accuracy vs caffeine.
2024	Kassim et al	Australia Ethiopia	Randomized, double-blind, placebo controlled, counterbalanced, crossover	40	Healthy adults aged 18–36 72.5% male; no psychiatric or neurological illness, mean education 14.5 years	1. Caffeine (200 mg) N=20 2. D-amphetamine (20 mg), N=20 3. Placebo	Spatial Span (Forward & Backward) for visual memory	Caffeine improved total spatial span score - Forward span: caffeine placebo - Backward span: caffeine, placebo
2024	Kruger et al	Canada	Randomized placebo-controlled trial, parallel, single-blind	127	Undergraduate students aged 18–39, mean age 20.4 ± 2.5; 38 male, 84 female, 5 non-binary; mostly White, East Asian, and South Asian	1. Caffeine (200 mg gum), N=61 2. Placebo (gum) N=66	Metronome Response Task (MRT) assessing mind wandering and attention	Caffeine improved mood and arousal, reduced boredom, sleepiness, and mental effort. No significant difference for spontaneous or deliberate mind-wandering. MRT variability and on-task responses improved significantly.
2025	Akyurek et al	The Netherlands	Randomized, double-blind, placebo controlled, crossover	48	Healthy university students, age 19–31 (Mean = 21.94, SD = 2.50); 24 males, 24 females; stratified by gender; no comorbidities reported	1. Placebo 2. Cocoa flavanols 3. Caffeine (200 mg) 4. Cocoa + Caffeine	Tasks assessing temporal attention (Rapid serial visual presentation), spatial attention (Visual search), and working memory (delayed recall)	Attentional Blink (AB): Caffeine improved AB recovery (faster reaction times) vs. placebo - Spatial Attention: caffeine showed improvements vs. placebo - Working Memory: Combination of caffeine + cocoa improved performance on some measures vs. placebo

Statistically significant change in outcomes based on p value <0.05, Total individuals 951. BMI: Body mass index, CPT: Continuous performance task, CRA: Compound Remote Associates, DSST: Digit Symbol Substitution Test, fMRI: Functional Magnetic Resonance Imaging, MRT: Metronome Response Task, NA: not available, PVT: Psychomotor Vigilance Task, RCTs: Randomized controlled trials, RNG: Random Number Generation, RTT: Reaction Time test, RVIP: Rapid Visual Information Processing, SD: Standard Deviation; SDC: Symbol Digit Coding, SWM: Spatial Working Memory, TMT: Trail Making test, UK: United Kingdom, USA: United States of America, VWM: Verbal Working Memory

Table 2: *Characteristics of the included studies.*

carryover effects (Barry et al., 2020; Franceschini et al., 2020; Kassim et al., 2023).

A consistent methodological strength across studies was the standardization of pre-test conditions, which typically included mandatory abstinence from caffeine for 12 to 24 hours prior to testing. In addition, participants were instructed to follow controlled dietary intake protocols and were assessed at predefined times of day to reduce circadian variability in cognitive performance. Several studies also examined contextual and individual-level factors that may modulate the cognitive effects of caffeine. Lanini et al. evaluated cognitive performance under fasted versus fed conditions, suggesting that metabolic state may influence caffeine's efficacy (Lanini et al., 2016). Souissi et al. investigated time-of-day effects, reporting differential outcomes depending on whether testing occurred in the morning or evening (Souissi et al., 2019).

The role of habitual caffeine consumption was explored, which found that individuals with low habitual intake tended to exhibit greater cognitive responsiveness to acute caffeine administration (Laatar et al., 2021; Lin et al., 2023). Wicht et al. systematically assessed expectancy effects, demonstrating that participants' beliefs about having consumed caffeine could modulate cognitive performance independently of the actual pharmacological exposure (Wicht et al., 2022).

Outcomes assessed

The included randomized controlled trials assessed a broad spectrum of cognitive domains relevant to caffeine's acute neuropsychological effects. The primary outcomes were focused on attention, working memory, and executive function, while secondary outcomes encompassed mood and arousal, psychomotor vigilance, and dual-task or motor coordination performance.

Attention was the most frequently evaluated domain and was typically measured using paradigms that assess sustained attention, selective attention, or attentional control. Tools such as the Rapid Visual Information Processing (RVIP) task (Haskell-Ramsay et al., 2018; Lin et al., 2023), the Continuous Performance Task (Kruger et al., 2024), and the Go/No-Go task (Wicht et al., 2022) were commonly used to quantify attentional performance, often through reaction time and accuracy metrics.

Working memory was assessed using both verbal and visuospatial paradigms, such as the n-back task (Lin et al., 2023), spatial span (Kassim et al., 2023; Waer et al., 2021), and digit span tasks (Kassim, 2024). These tests measure short-term memory capacity and updating ability, and were often employed in crossover or placebo-controlled settings. Executive function, a multidimensional domain encompassing inhibitory control, cognitive flexibility, and planning,

was assessed using tests such as the Stroop task (Konishi et al., 2018), Flanker task (Renda et al., 2015), the Zoo Map Test (Lanini et al., 2016), and the Jansari Assessment of Executive Functions (Franceschini et al., 2020). These tasks are designed to evaluate higher-order processing, especially under conditions requiring interference control or strategic planning.

Mood and arousal outcomes were often included as secondary endpoints, measured through self-report instruments evaluating alertness, fatigue, subjective energy, and emotional state (Bloomer et al., 2015; Kruger et al., 2024; Waer et al., 2021). These measures were typically collected alongside cognitive testing to explore psychophysiological correlates of performance. Psychomotor vigilance—reflecting both cognitive speed and alertness—was assessed using the Psychomotor Vigilance Task (PVT) in several trials (Souissi et al., 2019; Lanini et al., 2016), providing reaction time data in response to randomly timed stimuli. Finally, dual-task and motor performance domains were examined using protocols that combined cognitive and physical tasks, such as walking or postural control while completing memory tasks (Laatar et al., 2021; Waer et al., 2021). These designs were used to assess real-world multitasking ability and cognitive-motor integration.

Standardized tests

Standardized cognitive assessments across the included trials encompassed a variety of validated tools, each targeting specific domains of cognitive function. Sustained attention and working memory were frequently evaluated using the Rapid Visual Information Processing (RVIP) task (Haskell-Ramsay et al., 2018; Lin et al., 2023). The Go/No-Go task was employed to assess inhibitory control and impulse regulation (Barry et al., 2020; Wicht et al., 2022). Working memory capacity was commonly measured using the n-back task, particularly in Lin et al., which required participants to identify stimuli matching those presented 'n' steps earlier (Lin et al., 2023). Executive function, especially cognitive flexibility and selective attention, was examined through the Stroop Test (Konishi et al., 2018; Van Den Berg et al., 2021). The Psychomotor Vigilance Task (PVT) was used to evaluate reaction time and sustained attention (Lanini et al., 2016; Souissi et al., 2019).

Additional measures were incorporated to explore broader cognitive processes. The Digit Span and Spatial Span tasks, targeting verbal and visuospatial short-term memory, were used (Kassim, 2024; Kassim et al., 2023). Processing speed and task-switching were assessed using the Trail Making Test (TMT) (Bloomer et al., 2015). The Attentional Network Task (ANT) provided a multidimensional analysis of alerting, orienting, and executive attention (Franceschini et al., 2020). Collectively, these instruments enabled a comprehensive evaluation of the acute cognitive effects of caffeine across diverse functional domains.

Main results

The findings from the twenty randomized controlled trials included in this review demonstrate that acute caffeine intake positively affects several cognitive domains in healthy adults, particularly at low-to-moderate doses (100–200 mg). The most consistent improvements were observed in sustained attention, vigilance, and reaction time. These effects were notably evident in tasks such as the Rapid Visual Information Processing (RVIP), Psychomotor Vigilance Task (PVT), and Go/No-Go paradigms, especially among individuals with low habitual caffeine intake and under controlled experimental conditions (Haskell-Ramsay et al., 2018; Lin et al., 2023; Souissi et al., 2019). A summary of study-specific effects across cognitive domains is provided in Table 3.

Working memory also showed favorable responses to caffeine, with enhancements noted in spatial and verbal domains. Benefits were more prominent in participants who consumed caffeine infrequently or were tested under fasting conditions. Tasks such as the n-back and span tests indicated improved performance at 200 mg caffeine doses (Kassim, 2024; Lanini et al., 2016; Waer et al., 2021). However, among high habitual caffeine users, the effects were attenuated or absent (Lin et al., 2023), suggesting that tolerance may diminish cognitive gains.

The effects of caffeine on executive functions were more heterogeneous. While some studies reported improvements in specific subdomains, such as inhibition (Barry et al., 2020), planning (Franceschini et al., 2020), and attention switching (Konishi et al., 2018), these benefits were not consistently observed across all cognitive tasks or participant groups. Higher doses ($\geq$300 mg) were frequently associated with diminished or null effects (Waer et al., 2021; Wicht et al., 2022), indicating a possible inverted U-shaped dose-response relationship.

Mood and arousal were generally enhanced following caffeine consumption. Participants reported greater alertness, elevated mood, and increased subjective energy, with the strongest effects observed during dual-task settings and among female participants (Laatar et al., 2021; Kruger et al., 2024). Notably, expectancy alone, believing one had consumed caffeine, was sufficient to elicit measurable performance changes in some studies (Wicht et al., 2022), emphasizing the role

Cognitive Domain	Study (Author, Year)	Effect Summary
Attention	Renda et al., 2015	Improved attention
	Haskell- Ramsey et al.,2018	Improved attention and reaction time
	Soiussi et al., 2019	Improved reaction time and vigilance
	van der Berg et al, 2020	Improved reaction time and accuracy
	Lin et al., 2023	Enhanced attentional control
	Wicht et al., 2022	Attentional engagement under both pharmacological and expectancy conditions
	Kruger et al., 2024	Improved auditory attention (auditory CPT)
	Lanini et al., 2016	Personalized doses improved attention in low habitual users
	Akyurek et al., 2025	Improved attention blink and spatial attention
	Bloomer et al., 2015	No impact on attention
	Ullrich et al., 2015	No impact on attention
	DeLongis et al., 2022	Improves sustained attention
Working Memory	Lin et al., 2023	Improved n-back performance
	Kassim et al., 2023	There is no main effect on spatial and verbal working memory
	Lanini et al., 2016	Dose and habitual use moderated working memory effects
	Waer et al., 2021	Dose-dependent working memory improvements
	Zabelina et al., 2020	No effect of caffeine on working memory
	Kassim et al., 2024	Negatively impact spatial working memory performance
Executive Function	Renda et al., 2015	Improved executive function
	Barry et al., 2020	Improved inhibition and response selection in a two-choice task
	Franceschini et al., 2020	Task-specific improvements (e.g., attention shifting)
	van der Berg et al., 2020	Improved executive function
	Konishi et al., 2018	Enhanced text reading speed, variable EF outcomes
Mood and Arousal	Waer et al., 2021	Increased alertness during dual-task conditions (women)
	Laatar et al., 2021	Higher energy and alertness under dual-tasking
	Kruger et al., 2024	Reduced mental fatigue and improved mood/arousal
	Zabelina et al., 2020	Decreased sadness
	DeLongis et al., 2022	Higher levels of physical and mental energy, and lower levels of mental and physical fatigue
Dual Tasking / Motor	Laatar et al., 2021	Improved coordination in cognitive-motor tasks
	Waer et al., 2021	Dose-dependent balance and motor coordination gains
	Bloomer et al., 2015	Improved cognitive and motor task integration
	Laatar et al., 2021	No impact on dual task or motor performance
Convergent thinking	Zabelina et al., 2020	Enhanced problem-solving abilities
Divergent thinking	Zabelina et al., 2020	No significant effects on creative idea generation

Summary of study-specific cognitive outcomes following acute caffeine administration, categorized by cognitive domain. CPT = Continuous Performance Task; fMRI = functional Magnetic Resonance Imaging; PVT= Psychomotor Vigilance Task; RCT = Randomized Controlled Trial. Findings reflect studies included in the final systematic review (n = 20).

Table 3: *Summary of outcomes of caffeine intake by cognitive domain.*

of psychological factors in modulating caffeine's cognitive effects. Caffeine also appeared to enhance motor coordination and dual-task integration, with improved postural control and performance in combined cognitive-motor tasks. These effects were dose-dependent, with 100–200 mg outperforming both placebo and higher caffeine doses (Laatar et al., 2021; Bloomer et al., 2015; Waer et al., 2021).

Nevertheless, several studies reported null or inconsistent findings, particularly those involving small sample sizes, low-complexity tasks, or populations with high baseline caffeine tolerance (Ullrich et al., 2015; Zabelina & Silvia, 2020). Such heterogeneity underscores the importance of individual and contextual variables, such as habitual intake, task design, and psychological expectancy, in determining the cognitive efficacy of caffeine.

Risk of bias in individual studies

The RoB-2 assessment of the 20 RCTs included revealed significant variability in methodological rigor (Table 4, Figure 2). While some studies demonstrated low risk of bias across all domains (Haskell-Ramsay et al., 2018; Waer et al., 2021), others exhibited high risk in critical areas, such as outcome reporting (Franceschini et al., 2020). Notably, Domain 3 (missing outcome data) was frequently rated as low risk, suggesting robust handling of attrition. However, Domain 5 (selection of reported results) often lacked clarity, raising concerns about potential selective reporting. In particular, the conflict of interest was assessed as a high risk of bias in the overall risk of bias assessment owing to the direct involvement of employees from the sponsoring industry in all stages of the research process, including study design, data analysis, and reporting (De Longis et al., 2022). These inconsistencies highlight the need for stricter adherence to CONSORT guidelines to minimize bias in future trials (Hopewell et al., 2025).

Common weaknesses and strengths

A recurring issue was unclear randomization (Domain 1), seen in Bloomer et al. and Kassim et al., which undermines confidence in baseline comparability (Bloomer et al., 2015; Kassim et al., 2023). Conversely, measurement bias (Domain 4) was generally well-controlled, with most studies like Akyürek et al. and Kruger et al. using objective outcomes (Akyürek et al., 2025; Bloomer et al., 2015). Surprisingly, deviations from interventions (Domain 2) were rarely problematic, except in

Zabelina & Silvia et al., where high risk suggested protocol violations (Zabelina & Silvia, 2020). The overall risk of bias was frequently "unclear" due to insufficient reporting, emphasizing the importance of transparent methodology. The mixed RoB-2 ratings would have complicated a meta-analysis, as high-risk studies may skew pooled estimates. Studies with unclear overall bias warrant cautious interpretation. To enhance reliability, future research should include pre-registered protocols, detailed randomization methods, and justify exclusions (Hopewell et al., 2025). The predominance of low risk in Domain 3 is promising, but addressing gaps in Domain 1 and Domain 5 is critical for strengthening clinical evidence.

Discussion

In general, most studies indicate that caffeine has a positive impact on various aspects of cognition, memory and other cognitive related states like mood and arousal, although results may vary depending on the dosage administered.

Our study concludes similar results to existing reviews, such as that conducted by Lorenzo Calvo et al., which, despite focusing on the effects of caffeine in sports, demonstrating improvements in accuracy, speed, and mood during exercise, also observed a positive impact on some aspects of memory (Lorenzo Calvo et al., 2021). This is also true of the systematic review conducted by Saavedra et al., which concluded that moderate doses of caffeine improve psychophysiological response in various contexts, increasing alertness and attention, and improving reaction time and dual task performance (Saavedra Velásquez et al., 2024). In contrast, the review of RCTs conducted by Mortaz-Hedjri et al., published in the Cochrane Library in 2007, found that the results of the studies analyzed were inconclusive regarding the benefits of caffeine for cognition and memory (Mortaz-Hedjri et al., 2007).

Among the studies analyzed, caffeine dosages ranged from 100 to 400 mg. However some authors such as Renda et al. and Souissi et al. administered caffeine based on body weight, with dosages between 3 and 6 mg/kg (Renda et al., 2015; Souissi et al., 2019). To assess various cognitive and memory functions, standardized tests were employed, most commonly the reaction time test (RTT). In the majority of studies, caffeine intake was verified prior to testing using either saliva samples or self-reported questionnaires. An exception was the study by Zabelina et al., which initiated the intervention without confirming prior caffeine intake (Zabelina & Silvia, 2020). While this introduces potential bias, it does not substantially alter the overall pattern of results found in this review.

Haskell-Ramsay et al. reported significant improvements in attention and reaction time with caffeine intake (Haskell-Ramsay et al., 2018), whereas Konishi et al. observed improvements only in selective (divided) attention, with no significant changes in other cognitive tests (Konishi et al., 2018). Souissi et al. found enhanced reaction time and vigilance, particularly in the morning (Souissi et al., 2019). Kassim et al. reported improved scores on the spatial span task following caffeine ingestion compared to placebo (Kassim, 2024). Kruger et al. observed enhanced mood and alertness, along with reduced mental fatigue and boredom (Kruger et al., 2024).

Notably, Akyürek et al. demonstrated that caffeine improved performance on the Attentional Blink task (Akyürek et al., 2025). In contrast, Kassim et al. reported no statistically significant differences between caffeine and placebo in working memory tasks (Kassim et al., 2023). Of particular interest, the study by Waer et al. was the only one to distinguish between high and low caffeine doses. They found that low doses of caffeine significantly improved reaction time, whereas high doses of caffeine produced no differences when compared to placebo (Waer et al., 2021).

While caffeine-related improvements were more consistently observed in attention-related tasks, this pattern should not be interpreted as a generalized enhancement of executive function. Attention and executive control, although related, rely on partially distinct neural mechanisms. It is therefore possible that enhancements in vigilance or processing speed may not translate into improved higher-order executive performance, and in some contexts could potentially reflect domain-specific modulation rather than global cognitive enhancement. Future studies should incorporate comprehensive cognitive batteries to evaluate whether attentional gains occur independently of—or potentially at the expense of—executive control processes.

The dose-related effects of caffeine in our studies favor a low to moderate dose of caffeine (100–200 mg) for cognitive improvement, as higher doses (300–400 mg) as shown by Waer et al. and Wicht et al. had no statistical difference with placebo or detrimental effects (Waer et al., 2021; Wicht et al., 2022). This has been described in the literature as an inverted U-shaped dose-response curve, with moderate doses outperforming low and high doses in memory consolidation (Borota et al., 2014) and mental arithmetic performance (Kase & Schoelles, 2009). Only the study of Souissi et al. using a high dose of caffeine (dosage of 6 mg/kg) showed an improvement in reaction time and vigilance (Souissi et al., 2019).

The risk of bias (RoB-2) assessment of the included

Study name	Domain 1	Domain 2	Domain 3	Domain 4	Domain 5	Overall
Bloomer 2015	SC	SC	Low	SC	SC	**Some concern**
Renda 2015	Low	Low	High	Low	Low	**High**
Ullrich 2015	SC	SC	Low	Low	Low	**Some concern**
Lanini 2016	Low	Low	Low	Low	Low	**Low**
Haskel-Ramsey 2018	Low	Low	Low	Low	Low	**Low**
Konishi 2018	Low	SC	Low	Low	SC	**Some concern**
Souissi 2019	Low	Low	Low	Low	SC	**Some concern**
Barry 2020	SC	Low	Low	Low	SC	**Some concern**
Franceschini 2020	SC	Low	Low	Low	High	**High**
van der Berge 2020	SC	Low	Low	Low	SC	**Some concern**
Zabelina 2020	Low	High	SC	Low	Low	**High**
Laatar 2021	Low	Low	Low	Low	Low	**Low**
Waer 2021	Low	Low	Low	Low	SC	**Some concern**
DeLongis 2022	Low	Low	Low	Low	SC	**Some concern**
Wicht 2022	SC	SC	Low	Low	SC	**Some concern**
Kassim 2023	SC	SC	Low	SC	SC	**Some concern**
Lin 2023	Low	Low	SC	Low	Low	**Some concern**
Kassim 2024	Low	Low	SC	Low	High	**High**
Kruger 2024	Low	Low	Low	Low	SC	**Some concern**
Akyurek 2025	Low	Low	Low	Low	SC	**Some concern**

Domains: (1) Bias arising from the randomization process; (2) Bias due to deviations from intended interventions; (3) Bias due to missing outcome data; (4) Bias in measurement of the outcome; and (5) Bias in selection of the reported result. SC: some concern.

Table 4: *Risk of bias assessment (RoB-2).*

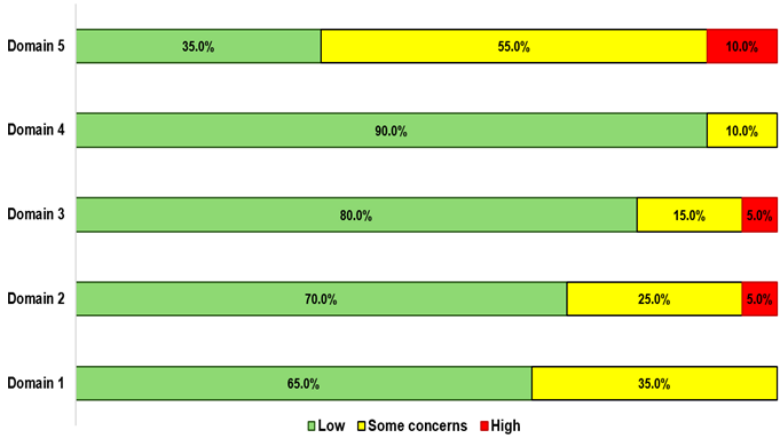

Figure 2: *Proportion of risk of bias in the five domains: (1) Bias arising from the randomization process; (2) Bias due to deviations from intended interventions; (3) Bias due to missing outcome data; (4) Bias in measurement of the outcome; and (5) Bias in selection of the reported result.*

studies reveals notable variations across different domains, which significantly influences the certainty of the evidence presented in the systematic review. In Domain 1, relating to bias arising from the randomization process, the majority of studies (approximately 60%) were classified as having some level of concern, while a considerable proportion also reached a low risk level. This suggests that randomization was generally executed correctly, although improvements could increase confidence in the findings. In Domain 2, relating to deviations from intended interventions, the majority of studies were classified as low risk, which positively contributed to the overall certainty of the evidence. However, in Domain 3, which assesses bias due to missing outcome data, several studies (around 25%) were classified as high risk, particularly those with incomplete outcome reporting. This raises concerns about the reliability of the results, especially in studies with high attrition rates. Domain 4, which focuses on outcome measurement, showed a combination of low and some concern ratings, indicating that while many studies employed appropriate outcome measures, some did not adequately report their methodologies. Finally, in Domain 5, bias in the selection of reported outcomes showed a significant number of studies at high risk, particularly those funded by industry, which could introduce bias due to selective reporting practices. Overall, these findings suggest that confidence in the evidence is low or moderate for attention-related outcomes, as most studies demonstrated robust methodologies, whereas confidence in executive function (EF) results is lower, particularly due to the higher proportion of studies with concerns or high risk across the reporting and measurement domains. The presence of funding or reporting issues, particularly in studies demonstrating high risk in Domain 5, further emphasizes the need for caution when interpreting these results and highlights the importance of conducting future research with rigorous methodologies to strengthen the certainty of the evidence.

Strengths and limitations

This review includes studies with different designs, such as double-blind, crossover, and placebo-controlled studies, which provide robust comparisons of results. We also highlight as a methodological strength the use of standardized cognitive tests previously approved for this purpose. This contributes to the validity and reliability of the results obtained, allowing for a more precise comparison with previous studies and facilitating the interpretation of the effects of caffeine on cognitive function. Another important aspect is that most studies have good control over variables, with well-defined exclusion criteria, which avoids bias. By focusing exclusively on healthy adults and stratifying results based on caffeine dose, this review addresses a significant gap in the existing literature and offers a more nuanced, clinically relevant synthesis of cognitive effects of caffeine. The generalizability of this review's findings is enhanced by the inclusion of RCTs across diverse geographic locations, with participants ranging in age from 18 to 60 years and exhibiting varied levels of habitual caffeine consumption. Most studies targeted healthy adults without neurological or psychiatric disorders, making the findings most applicable to this population.

However, several limitations must be acknowledged. The majority of participants were young to middle-aged adults, often university students or physically active individuals. The existence of rigorous exclusion criteria that provide internal validity may limit the applicability of the results to older populations, non-caffeine consumers or individuals with comorbidities. Furthermore, caffeine was predominantly administered in controlled settings using capsules, gum, coffee, or energy drinks—modalities that may not fully reflect real-world consumption patterns, which often involve varied beverage types, doses, and timing. The outcome measures of cognition varied significantly. Each study assessed different types of cognitive functions using a variety of tools. Variability in cognitive assessment tools and dosing regimens across the included studies may further affect generalizability. While this heterogeneity reflects real-world complexity, it also introduces variability in outcomes and direct comparisons. Furthermore, considerable heterogeneity was identified among the included trials with respect to cognitive outcomes, assessment tools, and caffeine dosing protocols. Such variability restricts the generalizability of the findings and further limits the feasibility of quantitative pooling. Therefore, this systematic review employed a narrative synthesis approach, as the substantial methodological and clinical heterogeneity among the included studies precluded a valid meta-analytic aggregation. Explicit acknowledgment of both methodological quality issues and inter-study heterogeneity provides a more comprehensive justification for adopting this approach.

Implications for practice and future research

This systematic review highlights that caffeine consumption particularly at low to moderate doses (100–200 mg) can enhance specific cognitive functions such as attention, reaction time, and certain aspects

of working memory in healthy adults. These findings have practical implications for both clinical practice and everyday settings where cognitive performance optimization is sought without pharmacological intervention.

For clinicians, understanding the cognitive effects of caffeine can support evidence-based guidance for individuals seeking safe strategies to enhance mental alertness. This is particularly relevant for populations engaged in tasks that require sustained attention or rapid processing. Furthermore, these findings may inform practical recommendations regarding moderate daily coffee consumption to optimize cognitive benefits while minimizing the risk of adverse effects. From a policy standpoint, the results underscore the importance of establishing public consumption guidelines that acknowledge potential cognitive benefits alongside the known risks of excessive caffeine intake. Public health communications could promote moderate caffeine use as a potential cognitive enhancer while discouraging high doses that may pose health risks.

This review also identifies several key areas for future research. RCTs should further investigate individual variability in caffeine response, considering factors such as age, habitual consumption, genetic differences, and sex-related variations, to support more personalized recommendations, standardizing caffeine doses and administration protocols for comparisons between studies. More research is required to elucidate the dose-dependent effects of caffeine. Additionally, the long-term cognitive effects and interactions with lifestyle factors remain underexplored. Further studies should employ standardized and sensitive cognitive assessments to refine understanding across a broader range of cognitive domains. Although the evidence supports beneficial cognitive effects of caffeine in healthy adults, caution is warranted when generalizing these findings to broader or more clinically diverse populations, including habitual high-dose consumers, who may experience tolerance and altered metabolic responses. Additionally, the restriction to English-language studies should be acknowledged as a limitation, as it introduces a potential language bias that may have excluded relevant evidence from non-English publications. Overall, this review provides a robust and targeted evidence base for understanding the cognitive effects of caffeine in healthy adults, while highlighting the need for cautious interpretation and further research to extend these findings to other populations.

Conclusion

In summary, the information analyzed in this review suggests that low to moderate doses (100–200 mg) of caffeine has a positive effect on cognition, including attention, memory, and performance on mental tasks, in young, healthy adults. Although caffeine provides potential benefits, caffeine is not exempted from adverse effects that are especially present in high doses intake. Definitely, we suggest healthcare professionals recommend use of caffeine individually and according to necessities promoting responsible consumption. It is important to consider different populations, as the effect of caffeine may vary depending on factors such as age, sex, and genetics. We highlight the need for further standardized studies that include these factors, which would contribute to its generalization to broader populations.

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Conflicts of Interest

The authors declare no conflict of interest.

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