



The effect of caffeine on human quality of life: Myths and realities

Efecto de la cafeína en la calidad de vida de las personas, mitos y realidades

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ABSTRACT

Introduction: caffeine is the most widely consumed psychoactive agent globally. Historically surrounded by controversies, current scientific evidence reveals a complex coexistence of potential benefits and risks dependent on dosage and individual characteristics. Objective: to analyze the impact of caffeine consumption on people's quality of life, critically examining myths and realities in light of the most recent scientific evidence. Methods: a descriptive and narrative literature review was conducted through standardized searches in academic databases (PubMed, Scopus, SciELO) for publications between 2020 and 2026, selecting and qualitatively analyzing clinical and epidemiological evidence. Development: caffeine metabolism varies based on polymorphisms of the CYP1A2 gene. Moderate consumption (3 to 5 cups daily) disproves the myth of arrhythmogenic risk and is inversely associated with the risk of type 2 diabetes, dementia, liver diseases (steatosis and cirrhosis), and hepatocellular carcinoma, while also serving as an ergogenic aid in sports. However, high intake increases the risk of acute myocardial infarction and causes adverse effects such as insomnia, anxiety, and dependence. In pregnant women, intake is dose-dependently associated with a higher risk of small-for-gestational-age newborns. Furthermore, energy drinks represent a distinct cardiovascular and behavioral risk for children and adolescents. Conclusions: moderate caffeine consumption can be part of a healthy lifestyle in adults. However, recommendations must be individualized based on genetic, physiological, and safety factors, especially in vulnerable populations.

Keywords: Caffeine; Coffee; Cardiovascular diseases; Cognitive function; Energy drinks

RESUMEN

Introducción: la cafeína es el agente psicoactivo más consumido a nivel mundial. Históricamente rodeada de controversias, la evidencia científica actual revela una compleja coexistencia de beneficios potenciales y riesgos dependientes de la dosis y de factores individuales. Objetivo: analizar el impacto del consumo de cafeína en la calidad de vida de las personas, examinando críticamente los mitos y realidades a la luz de la evidencia científica más reciente. Métodos: se realizó una revisión bibliográfica de tipo descriptiva y narrativa mediante búsquedas estandarizadas en bases de datos académicas (PubMed, Scopus, SciELO) de publicaciones entre 2020 y 2026, seleccionando y analizando cualitativamente la evidencia clínica y epidemiológica. Desarrollo: el metabolismo de la cafeína varía según polimorfismos del gen CYP1A2. El consumo moderado (3 a 5 tazas diarias) desmiente el mito del riesgo arritmogénico y se asocia inversamente con el riesgo de diabetes tipo 2, demencia, enfermedades hepáticas (esteatosis y cirrosis) y carcinoma hepatocelular, además de actuar como ayuda ergogénica en el deporte. Sin embargo, dosis elevadas incrementan el riesgo de infarto agudo de miocardio y provocan efectos adversos como insomnio, ansiedad y dependencia. En mujeres gestantes, la ingesta se asocia dosis-dependientemente con un mayor riesgo de recién nacidos pequeños para la edad gestacional. Asimismo, las bebidas energéticas representan un riesgo cardiovascular y conductual diferenciado para niños y adolescentes. Conclusiones: el consumo moderado de cafeína puede formar parte de un estilo de vida saludable en adultos. No obstante, las recomendaciones deben individualizarse según factores genéticos, fisiológicos y de seguridad, especialmente en poblaciones vulnerables.

Palabras clave: Cafeína; Café; Enfermedades cardiovasculares; Función cognitiva; Bebidas energéticas

INTRODUCTION

Caffeine is the most consumed psychoactive agent in the world. (1) Its presence in daily life is so ubiquitous that it is difficult to imagine the daily routine of millions of people without a cup of coffee, a serving of tea, or an energy drink. However, despite its popularity, caffeine consumption has historically been surrounded by controversies: while for decades it was associated with cardiovascular and oncological risks, recent scientific evidence has revealed a much more complex picture, in which potential benefits and adverse effects coexist, depending on the dose and individual characteristics of the consumer. (1,2)

El uso de plantas que contienen cafeína tiene raíces profundas en la historia de la humanidad. El café y el té se han consumido durante cientos de años y se han convertido en parte fundamental de las tradiciones culturales y la vida social de diversas civilizaciones. (1) El consumo de café se extendió de manera significativa en el mundo árabe durante los siglos XV y XVI, y llegó a Europa entre los siglos XVIII y XIX, donde inicialmente fue considerado un artículo de lujo. De forma paralela, el té se popularizó en China durante la dinastía Ming y en Gran Bretaña durante el siglo XVIII. Resulta notable que, antes de convertirse en bebidas de consumo cotidiano, tanto el café como el té fueron utilizados con fines medicinales, lo que evidencia que sus propiedades farmacológicas fueron reconocidas desde épocas tempranas. (3)

En la actualidad, la cafeína se encuentra de forma natural en los granos de café, las hojas de té, el cacao, la yerba mate y las bayas de guaraná, y también se sintetiza para añadirse a refrescos, bebidas energéticas y comprimidos destinados a reducir la fatiga. (4) Datos recientes de una encuesta representativa de la población estadounidense, realizada en 2022 con 49 700 consumidores, indican que aproximadamente el 69 % de la población consume al menos una bebida con cafeína al día, con una ingesta media de 210 mg diarios entre los consumidores. El café sigue siendo la fuente predominante, contribuyendo con el 69 % de la ingesta total de cafeína, seguido por los refrescos carbonatados (15,4 %), el té (8,8 %) y las bebidas energéticas (6,3 %). [5] Estos datos reflejan un incremento en la ingesta respecto a encuestas previas, acompañado de un cambio en los patrones de consumo de bebidas. (5)

Globally, total caffeine consumption is increasing, driven primarily by population growth, although per capita consumption has also risen in countries such as Brazil, Italy, and Ethiopia. Furthermore, a positive correlation exists between per capita caffeine consumption and indicators of human development and gross domestic product in coffee-importing countries. (6) Regarding demographic patterns, caffeine intake is highest in middle-aged adults (50 to 64 years) and lowest in younger age groups, and intake is significantly associated with age, ethnicity, smoking status, and working hours. (7)

From a health perspective, accumulated evidence suggests that moderate coffee consumption (3 to 5 standard cups per day) is consistently associated with a lower risk of various chronic diseases, without increasing the risk of cardiovascular diseases or cancer. (8) However, high caffeine intake can cause adverse effects such as insomnia, anxiety, migraine, and dependence, and recommended limits of 400 mg/day for non-pregnant adults and 200 mg/day for pregnant or lactating women have been established. The benefits and risks depend on both the amount consumed and individual physical condition, underscoring the need for a personalized approach. (2,8)

In this context, this article analyzes the impact of caffeine consumption on people's quality of life, critically examining the myths and realities surrounding this substance in light of the most recent scientific evidence. Both the beneficial effects attributed to moderate consumption and the risks associated with excessive consumption are addressed, with special attention to vulnerable populations and implications for clinical practice and public health.

METHODS

A descriptive and narrative literature review was conducted to analyze the impact of caffeine consumption on individuals' quality of life and health, critically examining the myths and realities surrounding this substance. The study focused on the collection and qualitative synthesis of recent scientific evidence on the physiological effects of caffeine, evaluating both its protective benefits (cardiovascular, metabolic, cognitive, and hepatic) and its dose-dependent adverse effects, as well as its implications for vulnerable populations.

Search Strategy

For the literature search, recognized academic databases (PubMed, Scopus, Web of Science, SciELO) and official publications from international organizations such as the American College of Cardiology, the American Cancer Society, and the International Society of Sports Nutrition were consulted. Standardized descriptors and free-text terms combined using Boolean operators (AND/OR) were employed, such as: “caffeine”, “coffee”, “cardiovascular diseases”, “type 2 diabetes”, “cognitive function”, “pregnancy”, “sports performance”, and “energy drinks”.

La estrategia de búsqueda sistemática abarcó principalmente publicaciones desde el 1 de enero de 2020 hasta el 30 de mayo de 2026, para garantizar la captura de la evidencia epidemiológica y clínica más actualizada (incluyendo estudios de aleatorización mendeliana y grandes cohortes como el UK Biobank). Se rescataron de manera excepcional textos teóricos e históricos fundamentales sobre la farmacodinamia y el metabolismo genético de la cafeína (ej. polimorfismos del CYP1A2) por su alta relevancia para el marco teórico.

Inclusion and exclusion criteria

The inclusion criteria for literature selection were:

- Original articles (randomized clinical trials, prospective cohort studies, and cross-sectional analyses), systematic reviews, dose-response meta-analyses, and high-impact narrative reviews.
- Studies that addressed specific variables and scenarios such as the risk of arrhythmias, the prevention of type 2 diabetes mellitus, hepatoprotection, the effects on sleep and anxiety, bone health, ergogenic use in sports, and gestational risks.
- Documents, international clinical guidelines, and official positions on nutritional management and caffeine consumption.

On the other hand, the exclusion criteria included: literature without peer review, publications not available in full text, purely subjective opinion articles without scientific foundation, and in vitro studies or animal models that did not offer a direct and pertinent clinical translation for the public health objective of this article.

Study selection process and reproducibility

To ensure the rigor and reproducibility of the study, the selection process was standardized. The initial screening of titles and abstracts was carried out independently by two reviewers to identify potentially eligible studies. The full texts of these articles were thoroughly reviewed. Any discrepancies between the two primary reviewers were resolved through discussion and consensus, requiring the intervention of a third reviewer when necessary. The entire process of identification, screening, eligibility, and inclusion was systematically documented and illustrated by creating a flow diagram adapted for narrative reviews.

Assessment of methodological quality

To ensure the reliability of the synthesized evidence, the included articles underwent a quality assessment. For the included narrative reviews, the SANRA scale (Scale for the Assessment of Narrative Review Articles) was applied, allowing evaluation of methodological rigor based on criteria such as justification of the article, statement of objectives, description of the literature search, and robust referencing. For systematic reviews and meta-analyses, the PRISMA guidelines were considered. For original empirical articles, the clarity of the design, sample size, risk of bias, control of confounding variables (e.g., smoking or sugar consumption), and the strength of the conclusions relative to the clinical objectives of this review were evaluated.

Data Analysis

The analysis of the information was conducted through a qualitative synthesis of the findings, organized around the different body systems and population consumption profiles. Given the narrative methodological design, no meta-analysis or combined statistical estimates were performed. Nevertheless, this standardized analytical approach enabled accurate identification of the geometric complexity of the dose-response curve, prioritizing the collection of robust evidence to demystify entrenched beliefs and offer well-founded recommendations for clinical practice and contemporary public health.

DEVELOPMENT

La cafeína (1,3,7-trimetilxantina) se absorbe de manera casi completa en el tracto gastrointestinal dentro de los primeros 45 minutos tras su ingestión, alcanzando concentraciones plasmáticas máximas entre los 15 minutos y las 2 horas posteriores. Una vez absorbida, se distribuye ampliamente por todos los tejidos corporales y atraviesa con facilidad la barrera hematoencefálica, lo que explica sus efectos centrales sobre el estado de alerta y la cognición. En el hígado, la cafeína es metabolizada por el sistema enzimático del citocromo P-450, particularmente por la isoforma CYP1A2, responsable de aproximadamente el 95 % de su biotransformación. Los principales metabolitos resultantes son la paraxantina, la teofilina y la teobromina, que posteriormente se degradan hasta ácido úrico y se excretan por vía renal. (1)

The half-life of caffeine in adults typically ranges between 2.5 and 4.5 hours, but exhibits considerable interindividual variability. A single nucleotide polymorphism (SNP rs762551) in the CYP1A2 gene determines three genotypes —AA (rapid metabolizers), AC (intermediate), and CC (slow metabolizers)— with approximate prevalences of 46%, 44%, and 10%, respectively, as described by Montalvo-Alonso et al. (2026) in their study on CYP1A2 genotype and physical performance. (9) Carriers of the C allele exhibit reduced enzymatic activity, which translates into higher and more sustained plasma caffeine levels. In addition to genetics, environmental and physiological factors substantially modify metabolism: smoking accelerates elimination by up to 50%, oral contraceptives double the half-life, and during the third trimester of pregnancy it can reach 15 hours. (1)

From a pharmacodynamic perspective, the main mechanism of action of caffeine is the non-selective antagonism of adenosine receptors, particularly the A1 and A2A subtypes. Adenosine is a neuromodulator that promotes drowsiness and reduces neuronal excitability; by blocking its receptors, caffeine increases the release of neurotransmitters such as dopamine and norepinephrine, resulting in increased alertness, improved concentration, and reduced perception of fatigue. Guo et al. (2021) described in detail how the regulation of CYP1A2 is influenced by multiple factors, including the aryl hydrocarbon receptor pathway, additional transcription factors, and regulatory microRNAs, which contributes to the wide interindividual variability in response to caffeine. (10)

Caffeine and cardiovascular health: Debunking the myth of cardiac risk

For decades, popular belief and part of the medical community held that coffee consumption increased the risk of cardiovascular diseases. However, the accumulated scientific evidence in recent years has strongly refuted this claim. Kim et al. (2021), in a prospective study published in JAMA Internal Medicine with 386,258 participants from the UK Biobank, demonstrated that each additional cup of habitual coffee was associated with one 3 % lower risk of incident arrhythmia, including atrial fibrillation and supraventricular tachycardia. Mendelian randomization analyses provided no evidence that caffeine consumption increases arrhythmogenic risk. (11)

In line with these findings, the 2023 American College of Cardiology/American Heart Association guideline for the management of atrial fibrillation, published by Joglar et al. (2024), states that recommending caffeine abstinence to prevent episodes of atrial fibrillation has no demonstrated benefit. 1 randomized clinical trial of caffeine showed no difference in the risk of postoperative atrial fibrillation, and observational longitudinal studies have found that caffeine consumed in usual amounts is not associated with higher risk or is associated with lower risk of incident atrial fibrillation. (12)

Nevertheless, the relationship between caffeine and cardiovascular health is complex and depends on the outcome evaluated. Shaban et al. (2026), in an updated meta-analysis published in BMC Cardiovascular Disorders that included 38 studies and more than 2.8 million participants, found a significant positive association between high coffee consumption and the risk of acute myocardial infarction. (13) Dewland et al. (2025), in a review published in the European Heart Journal, concluded that, despite conventional concern, available data suggest that moderate coffee consumption is associated with a lower risk of hypertension, type 2 diabetes, myocardial infarction, arrhythmias, heart failure, and even all-cause mortality. (14)

Caffeine and type 2 diabetes mellitus: a paradoxical protective effect

One of the most robust and reproducible findings in the caffeine literature is the inverse association between coffee consumption and the risk of type 2 diabetes mellitus (T2DM).

Henn et al. (2025), in a study published in *The American Journal of Clinical Nutrition* based on three large US prospective cohorts (Nurses' Health Study, NHS II, and Health Professionals Follow-up Study) with more than 3,6 million person-years of follow-up and 13 281 incident cases of T2DM, confirmed that each additional cup of coffee without additives was associated with a 10 % reduction in the risk of T2DM. (15)

A particularly relevant finding of this study was that the addition of sugar significantly attenuated the protective association, while the addition of cream did not modify it. These results have direct practical implications for dietary recommendations: the benefit of coffee on the risk of T2DM depends in part on how it is consumed. (15)

Paradoxically, short-term metabolic studies have shown that caffeine acutely reduces insulin sensitivity. However, chronic consumption of caffeinated coffee (4 to 5 cups daily) for up to 6 months does not affect insulin resistance (1). This suggests that tolerance develops to the acute adverse effect, or that the non-caffeine components of coffee—such as antioxidant polyphenols and chlorogenic acid—exert beneficial effects on hepatic glucose metabolism that compensate for the negative effect of caffeine. Mohamed et al. (2024), in a comprehensive review published in *Diabetes & Metabolic Syndrome*, confirmed that both caffeinated and decaffeinated coffee are associated with a lower risk of T2DM, and that consuming up to 400 mg/day (1 to 4 cups) is associated with a lower risk of this disease (16).

Caffeine and cognitive function: protection against dementia

Zhang et al. (2026), in a large-scale prospective study published in *JAMA* that included 1 131 821 participants from the Nurses' Health Study and Health Professionals Follow-up Study cohorts with up to 43 years of follow-up, documented 11 033 cases of incident dementia. The results showed that higher consumption of caffeinated coffee was significantly associated with a lower risk of dementia, as well as a lower prevalence of subjective cognitive decline (17).

The dose-response analysis revealed a non-linear relationship, with the most pronounced associations observed with a consumption of approximately 2 to 3 daily cups of caffeinated coffee, without additional benefits at higher levels. This plateau pattern is biologically plausible, given that the enzymatic activities involved in caffeine metabolism may become saturated at higher doses, and excessive consumption may negatively affect sleep quality or increase anxiety, potentially counteracting the neuroprotective benefits. Notably, decaffeinated coffee was not associated with a lower risk of dementia, suggesting that caffeine is the key component of this protective association. (17)

Cornelis et al. (2022), in a study published in *Annals of Neurology* that combined data from the Rush Memory and Aging Project and the UK Biobank, found more nuanced results: in the UK Biobank cohort, consumption of 200 to 400 mg/day of caffeine was associated with one 26 % lower risk of dementia, but in the smaller Rush MAP cohort, intake above 100 mg/day was paradoxically associated with higher risk. The authors suggested that Lewy bodies could be the link between caffeine and cognitive protection, since caffeine intake was inversely associated with the presence of neocortical Lewy bodies in the postmortem neuropathological analysis. (18)

Caffeine and Cancer: From Suspicion to Evidence of Protection

The relationship between caffeine consumption and cancer risk has undergone a remarkable transformation. While early studies raised concern about a possible carcinogenic effect, current evidence points in the opposite direction. The American Cancer Society guideline for cancer prevention through diet and physical activity, published by Rock et al. (2020), indicates that coffee consumption likely reduces the risk of liver and endometrial cancers, and there is evidence of a protective effect against cancers of the oral cavity, pharynx, larynx, and basal cell carcinoma of the skin. (19)

The most robust association is observed with hepatocellular carcinoma (HCC). Yu et al. (2023), in a meta-analysis published in *Nutrition and Cancer* that included 21 studies with 2,492,625 participants, found that higher coffee consumption was associated with a 47% lower risk of HCC. (20) Khalifa et al. (2025), in a review published in the *Journal of Viral Hepatitis*, confirmed that regular consumers of 2 to 3 cups per day have a 38% lower risk of HCC, a figure that rises to 41% with 4 cups per day. (21)

Caffeine and liver health: a multidimensional protective effect

Beyond the prevention of HCC, the evidence on the hepatoprotective effects of coffee is particularly compelling. The clinical guideline of the American College of Gastroenterology on nutrition in liver disease, published by Singal et al. (2025), highlights that coffee consumption is inversely associated with hepatic steatosis, advanced liver fibrosis, and even cirrhosis. These benefits have been observed in a broad spectrum of liver diseases, from hepatitis C to metabolic dysfunction-associated steatotic liver disease (MASLD) and alcoholic liver disease. (22)

Khalifa et al. (2025) described the underlying mechanisms: caffeine, as an adenosine receptor antagonist, inhibits the activation of hepatic stellate cells, which play a central role in fibrogenesis. Additionally, caffeine inhibits proinflammatory mediators such as TNF- α and IL-6, improves mitochondrial function, and reduces oxidative stress. Coffee polyphenols, particularly chlorogenic acid, provide additional protection against steatosis and fibrogenesis by improving lipid homeostasis. The hepatic benefits of coffee appear to reach a plateau with a consumption of 3 to 4 cups per day. (21)

Some studies have reported positive effects even with decaffeinated coffee, indicating that ingredients other than caffeine also mediate the liver benefits. The ACG guideline notes that caffeine is metabolized in the liver and that reduced levels of its degradation products correlate with the severity of liver disease, which raises the paradox that patients with advanced liver disease might benefit less if caffeine metabolites were the protective ingredients. (22)

Adverse Effects of Caffeine: Sleep, Anxiety, and Dependence

Despite the multiple benefits associated with moderate consumption, caffeine is not free from adverse effects, particularly when consumed in high amounts or in sensitive populations. Chang et al. (2025), in a meta-analysis of 22 crossover controlled trials with 956 participants published in *Sleep Medicine*, demonstrated that caffeine significantly reduces total sleep time by 34.67 minutes, sleep efficiency by 4.74%, and the proportion of slow-wave sleep by 1.01%, while prolonging sleep latency by 8.35 minutes. The effects were more pronounced in young consumers and with high doses. (23)

Regarding anxiety, Nascimento et al. (2026), in a systematic review published in *Stress and Health* that included 27 articles, confirmed a dose-dependent anxiogenic effect of caffeine. The administration of 400 mg has the potential to cause more pronounced changes in mood compared to doses of 200 mg, including nervousness, tension, and reduced calmness. However, regular consumers of high or moderate doses are less sensitive to these changes, a phenomenon related to pharmacological tolerance. Genetic polymorphisms in the adenosine A2A receptor significantly influence individual susceptibility. (24) Liu et al. (2024), in a meta-analysis published in *Frontiers in Psychology* with 546 participants, confirmed that caffeine increases the risk of anxiety, especially when the dose exceeds 400 mg. (25)

Regarding dependence, caffeine withdrawal is characterized by headache, marked fatigue, dysphoric mood, difficulty concentrating, and flu-like symptoms that appear after the abrupt cessation of habitual consumption. These symptoms peak between 1 and 2 days after discontinuation and have a total duration of 2 to 9 days, and can be alleviated by gradual dose reduction. (1)

Caffeine during pregnancy: evidence-based caution

Caffeine consumption during pregnancy represents an area where the evidence justifies particular caution. Caffeine freely crosses the placenta, and both the mother and the fetus have significantly reduced caffeine metabolism during gestation. Askari et al. (2024), in a dose-response meta-analysis published in *Critical Reviews in Food Science and Nutrition* that included 22 studies, demonstrated that caffeine intake was associated with a significantly increased risk of small-for-gestational-age newborns, with a 13% increase in risk per additional 100 mg of daily caffeine. In contrast, no significant association was found with preterm birth. (26)

Gleason et al. (2021), in a secondary analysis of the NICHD Fetal Growth Studies published in *JAMA Network Open* with 2 055 non-smoking women, found that even consumption of approximately 50 mg of caffeine per day (half a cup of coffee) was associated with lower birth weight ($\beta = -66$ g) and smaller neonatal arm and thigh circumferences, suggesting that adverse effects may occur at levels much lower than the recommended limit of 200 mg/day. (27)

Rohweder et al. (2024), in an integrative review published in *Reproductive Toxicology* that evaluated 59 articles, found associations between caffeine intake and pregnancy loss, low birth weight, cardiac and genital anomalies, greater body mass, and neurodevelopmental alterations, with effects often dose-dependent. (28)

James (2026), in a narrative review published in *Advances in Experimental Medicine and Biology*, argued that the evidence of harm is strong for miscarriage, stillbirth, and low birth weight, and that many studies report significant dose-response associations without a clearly identifiable safe consumption threshold. (29)

Caffeine and physical performance: solid ergogenic evidence

La cafeína es una de las ayudas ergogénicas más estudiadas y utilizadas en el ámbito deportivo. La posición oficial de la International Society of Sports Nutrition (ISSN), publicada por Guest et al. (2021), establece que la suplementación con cafeína mejora de manera aguda diversos aspectos del rendimiento físico, incluyendo la resistencia muscular, la velocidad de movimiento, la fuerza muscular, el rendimiento en sprint, salto y lanzamiento, así como un amplio rango de acciones deportivas aeróbicas y anaeróbicas. Las dosis efectivas se sitúan entre 3 y 6 mg/kg de peso corporal, administradas aproximadamente 60 minutos antes del ejercicio. (30)

Stadheim et al. (2021), en un ensayo aleatorizado, doble ciego y controlado con placebo publicado en *Medicine and Science in Sports and Exercise* con 23 atletas de élite, demostraron que la cafeína (4,5 mg/kg) incrementó significativamente el tiempo hasta el agotamiento, el consumo máximo de oxígeno ($\text{VO}_{2\text{máx}}$) y el déficit de oxígeno, confirmando que la cafeína mejora el rendimiento en ejercicio de alta intensidad incluso en atletas altamente entrenados. (31)

Grgic (2021), in a review published in *Sports Medicine*, concluded that there is convincing evidence that caffeine is ergogenic for maximal strength (1RM), muscular endurance, speed, and power in different resistance exercises. Additionally, he noted that low doses of caffeine (2-3 mg/kg) appear to be comparably ergogenic to high doses (6 mg/kg), and that alternative sources such as caffeinated gums and gels also improve performance. (32) Lowery et al. (2023), in the official position of the ISSN on coffee and sports performance, confirmed that coffee as a beverage improves performance across a wide temporal range of activities, from reaction time to brief power exercises and aerobic endurance. (33)

Caffeine and Bone Health: A More Complex Relationship Than Expected

The relationship between caffeine consumption and bone health has historically been a cause for concern. In a review published in *Osteoporosis International*, Berman et al. (2022) described how antagonism of adenosine A1 receptors by caffeine could inhibit osteoblast-mediated bone formation and promote osteoclast-mediated bone resorption. However, clinical and population-based evidence offers a mixed picture that does not uniformly support this concern. (34)

Zhang et al. (2024), en un estudio prospectivo del UK Biobank con 487 594 participantes y un seguimiento mediano de 12,8 años publicado en *Bone*, encontraron que el consumo moderado de café (1 a 2 tazas diarias) se asoció con un menor riesgo de osteoporosis, con una relación no lineal. (35) Liu y Chai (2025), en un estudio publicado en *Scientific Reports* que combinó datos transversales del NHANES con análisis de aleatorización mendeliana, proporcionaron evidencia de una relación causal negativa entre la ingesta de cafeína y la osteoporosis, con una reducción del 60 % en el riesgo en el tercil más alto de consumo. (36)

Li et al. (2024), in a Mendelian randomization study published in *Postgraduate Medical Journal*, confirmed positive associations between genetically determined caffeine intake from tea or coffee and total bone mineral density, particularly in the age group of 45 to 60 years. (37) However, Asoudeh et al. (2023), in a dose-response meta-analysis published in *Critical Reviews in Food Science and Nutrition*, found that each additional 100 mg of caffeine was marginally associated with 1.2 % higher risk of fracture, although high coffee consumption was protective against fractures in men. (33,38)

Energy drinks and vulnerable populations: a differentiated risk

While moderate caffeine consumption from traditional sources is generally considered safe for healthy adults, energy drinks pose a distinct risk, particularly for children and adolescents. These drinks exceed the FDA-allowed caffeine concentration in soft drinks by 2 to 4 times, and their consumption has been associated with adverse cardiovascular effects, including elevated blood pressure, QT interval prolongation, palpitations, arrhythmias, and reported cases of Takotsubo cardiomyopathy and coronary vasospasm. (39)

Oberhoffer et al. (2023), in a randomized, single-blind, placebo-controlled clinical trial published in *Pediatric Research*, demonstrated for the 1st time that acute consumption of a weight-adjusted energy drink was associated with significantly higher 24-hour systolic and diastolic blood pressure in healthy children and adolescents. (40)

Menzel et al. (2025), in the EDKAR study published in the *European Journal of Epidemiology*, first evaluated the effects of chronic high consumption of energy drinks in adolescents aged 15 to 18 years. Although they found no significant differences in cardiac parameters between chronic consumers and controls, half of the high consumers reported having experienced adverse effects, and this group exhibited higher alcohol consumption, higher smoking rates, and shorter sleep duration (41).

CONCLUSIONS

It is essential to recognize that these limits represent general recommendations and that individual responses vary considerably depending on genetic, physiological, and environmental factors. Health professionals should consider the potential pharmacological interactions of caffeine because multiple medications—including quinolone antibiotics, cardiovascular drugs, bronchodilators, and antidepressants—can delay its elimination and increase its half-life. Current evidence does not justify recommending caffeine or coffee consumption for disease prevention; however, for adults who are not pregnant or lactating and who do not have specific health conditions, moderate consumption of coffee or tea can be part of a healthy lifestyle.

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CONFLICT OF INTEREST

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