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CAFFEINE AS A CARDIOPROTECTIVE AND CARDIOTOXIC AGENT: A REVIEW OF RECENT EVIDENCE

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ABSTRACT

Caffeine is the most widely consumed psychoactive substance worldwide and is ingested daily in coffee, tea, cocoa, energy drinks, and dietary supplements. Its cardiovascular effects remain controversial because both beneficial and harmful associations have been reported. This review synthesizes recent evidence on the cardioprotective and cardiotoxic effects of caffeine, with particular attention to dose-response relationships, habitual versus acute exposure, product type, arrhythmias, blood pressure, heart failure, endothelial function, and genetic variability in caffeine metabolism. Available evidence from large cohort studies and reviews indicates that moderate habitual intake, particularly from traditional coffee consumption, is generally associated with a favorable cardiovascular profile, including lower cardiovascular and all-cause mortality and a lower risk of incident heart failure in some populations (Chieng et al., 2022; Poole et al., 2017; Stevens et al., 2021). Moderate intake does not appear to increase atrial fibrillation risk in the general population and may be neutral or modestly favorable in observational studies (Caldeira et al., 2013; Cheng et al., 2014; Surma et al., 2023). In contrast, acute high-dose exposure, especially from energy drinks and concentrated stimulant products, may increase blood pressure, provoke sympathetic overstimulation, and contribute to electrocardiographic changes such as QTc prolongation in susceptible individuals (Mandato et al., 2025; Voskoboinik et al., 2019). These effects are modified by individual metabolic variability, especially CYP1A2-related differences, lifestyle factors, baseline tolerance, and co-exposures (Cornelis et al., 2006; Palatini et al., 2009). Overall, the cardiovascular effects of caffeine are best understood as dose dependent, context dependent, and biologically heterogeneous. Moderate intake appears generally safe for most healthy adults, whereas high-dose products warrant greater caution and more personalized guidance.

KEYWORDS

Caffeine, Coffee, Cardiovascular Health, Arrhythmias, Heart Failure, Energy Drinks

CITATION

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1. Introduction

Caffeine is a naturally occurring methylxanthine and the most widely consumed psychoactive substance in the world. It is present in coffee, tea, cocoa-based products, energy drinks, pharmaceutical preparations, and dietary supplements. Because of this global reach, relatively modest physiological effects can become important at the level of public health and preventive cardiology. Historically, caffeine was often viewed with suspicion in cardiology, particularly in patients with hypertension, palpitations, or arrhythmias. However, more recent research has challenged an exclusively harmful view of caffeine and coffee by showing favorable or neutral associations with several long-term cardiovascular outcomes (Grosso et al., 2017; Poole et al., 2017).

The contemporary literature suggests that the cardiovascular profile of caffeine is highly dependent on dose, timing, source, co-ingested ingredients, and host susceptibility. Moderate coffee consumption is frequently associated with lower cardiovascular and all-cause mortality, whereas concentrated stimulant products may provoke hemodynamic and electrophysiological disturbances (Chieng et al., 2022; Mandato et al., 2025; Voskoboinik et al., 2019). These divergent findings have encouraged a more nuanced interpretation in which caffeine is seen as a substance with both potentially cardioprotective and potentially cardiotoxic effects.

From a mechanistic perspective, caffeine primarily blocks adenosine receptors, especially A1 and A2A receptors. Through this action it may alter autonomic tone, vascular resistance, coronary blood flow, platelet activity, and cellular signaling (Marcinek et al., 2024). At higher concentrations, caffeine can also influence phosphodiesterase activity and intracellular calcium handling, which may contribute to increased contractility, sympathetic tone, and electrophysiological instability (Voskoboinik et al., 2019). At the same time, coffee is a chemically complex beverage that contains many compounds other than caffeine, including chlorogenic acids and polyphenols. This means that studies focused on coffee consumption do not always map directly onto research on isolated caffeine exposure (Grosso et al., 2017; Poole et al., 2017).

Another major source of heterogeneity is interindividual metabolism. Genetic differences, particularly involving CYP1A2, may substantially influence caffeine clearance and the duration of cardiovascular exposure (Cornelis et al., 2006; Palatini et al., 2009). Lifestyle factors such as smoking, habitual caffeine use, medication use, and pregnancy may further modify caffeine pharmacokinetics and pharmacodynamics. Therefore, cardiovascular responses to caffeine cannot be assumed to be identical across all individuals.

Against this background, the aim of the present review is to examine the available evidence on caffeine as both a cardioprotective and cardiotoxic agent. The review focuses on cardiovascular mortality, heart failure, arrhythmias, blood pressure, endothelial and inflammatory pathways, high-dose stimulant exposure, and the role of metabolic and genetic variability. The goal is not to portray caffeine as uniformly beneficial or harmful, but rather to provide a balanced and clinically relevant synthesis of the current evidence.

2. Methodology

This manuscript was prepared as a structured narrative review of recent evidence on caffeine and cardiovascular health. The reporting logic was aligned with the general structure of a review article and with the section order requested by IJITSS. The review was not designed as a registered systematic review or meta-analysis; rather, it was intended as a clinically focused synthesis emphasizing high-value evidence, methodological transparency, and balanced interpretation.

A structured literature search was conducted in major biomedical databases, including PubMed, Scopus, and Web of Science. Search terms combined the concepts of caffeine, coffee, cardiovascular disease, arrhythmia, atrial fibrillation, ventricular arrhythmia, heart failure, blood pressure, hypertension, endothelial function, energy drinks, CYP1A2, and adenosine receptors. Additional papers were identified through citation tracking and by screening the reference lists of major review papers, umbrella reviews, and meta-analyses.

Priority was given to large prospective cohort studies, systematic reviews, meta-analyses, clinically relevant review papers, and selected mechanistic studies that provided biologically meaningful context for cardiovascular outcomes. Publications were considered eligible when they evaluated mortality, incident

cardiovascular disease, arrhythmias, heart failure, blood pressure, endothelial function, cardiac electrophysiology, or modifiers of caffeine metabolism relevant to cardiovascular interpretation.

Particular attention was paid to the distinction between coffee as a complex dietary exposure, isolated caffeine as a pharmacologically active compound, and energy drinks as mixed stimulant products. This distinction was methodologically important because it helps prevent overgeneralization. Coffee, caffeine tablets, and high-caffeine energy drinks are not interchangeable exposures, and their cardiovascular implications may differ because of beverage matrix, co-ingredients, dose density, and rate of consumption.

Findings were synthesized narratively rather than pooled quantitatively. Where the literature was mixed, conclusions were stated conservatively. Mechanistic studies were used to support biological plausibility but were not treated as substitutes for clinically meaningful outcome data. This approach was chosen to create a review that is readable, defensible, and suitable for academic submission.

3. Results

The literature as a whole suggests that the cardiovascular effects of caffeine are best understood as dose dependent and context dependent. Moderate habitual intake, especially through coffee, is frequently associated with a favorable or neutral cardiovascular profile. In contrast, high acute intake from energy drinks and concentrated stimulant products is more often associated with adverse hemodynamic and electrophysiological outcomes (Chieng et al., 2022; Mandato et al., 2025; Voskoboinik et al., 2019). The results below summarize the major patterns that emerge from the recent literature.

3.1. Large prospective cohort studies evaluating coffee or caffeine consumption and cardiovascular outcomes

Large observational studies provide some of the strongest contemporary evidence concerning long-term cardiovascular associations with coffee intake. The UK Biobank analysis by Chieng et al. (2022) is especially important because it examined different coffee subtypes and assessed cardiovascular disease, arrhythmias, and mortality outcomes in a very large sample. Moderate coffee intake, particularly around two to three cups per day, was associated with lower risks of incident cardiovascular disease and lower mortality. Notably, beneficial associations were observed not only with ground coffee but also with instant and decaffeinated coffee, suggesting that non-caffeine constituents likely contribute to the observed effects (Chieng et al., 2022).

This pattern is consistent with umbrella reviews that have summarized multiple health outcomes across many meta-analyses. These reviews generally conclude that coffee consumption is associated with lower risk for several chronic diseases and lower mortality, while also emphasizing that observational associations do not establish causality (Grosso et al., 2017; Poole et al., 2017). In the cardiovascular context, the repeated observation of a J-shaped or U-shaped curve suggests that moderate habitual consumption may be linked to a favorable risk profile, but that excessive intake or different product types may not follow the same pattern (Poole et al., 2017).

Because decaffeinated coffee is also associated with favorable long-term outcomes in some cohorts, it is unlikely that caffeine alone explains all observed benefits. Instead, coffee appears to act as a composite exposure involving caffeine, antioxidants, polyphenols, and other non-caffeine constituents (Chieng et al., 2022; Grosso et al., 2017).

3.2. Mortality and all-cause outcomes

One of the most consistent findings in the long-term literature is the association between moderate coffee consumption and lower all-cause mortality. This association has been observed across different cohorts and remains one of the strongest signals in the field (Chieng et al., 2022; Poole et al., 2017). The mortality advantage may reflect several overlapping factors, including favorable metabolic profiles, behavioral correlates of moderate coffee use, and the biological effects of compounds found in coffee.

At the same time, these findings should be interpreted with caution. Observational studies cannot fully eliminate residual confounding, and cup-based intake estimates do not precisely capture caffeine dose. Nevertheless, the direction of association is sufficiently consistent across large studies to support the conclusion that moderate coffee consumption is not harmful to cardiovascular survival in the general population and may be favorable (Grosso et al., 2017; Poole et al., 2017).

3.3. Heart failure

The relationship between coffee consumption and heart failure has shifted substantially from older assumptions. In the past, caffeine was often viewed as undesirable in patients at risk of heart failure because of its stimulant and chronotropic effects. More recent evidence, however, suggests that moderate habitual coffee intake may be associated with lower incident heart failure risk (Poole et al., 2017; Stevens et al., 2021).

A machine-learning analysis of integrated cohort data from the Framingham Heart Study, the Atherosclerosis Risk in Communities (ARIC) Study, and the Cardiovascular Health Study found that higher coffee intake was associated with lower long-term heart failure risk (Stevens et al., 2021). Although such findings do not prove causality, they challenge the historical view that habitual coffee intake is intrinsically harmful to myocardial function in the general population.

Several biological explanations have been proposed for these observations. Moderate coffee exposure may influence alertness, physical performance, endothelial function, and inflammatory signaling in ways that may support cardiovascular resilience (Grosso et al., 2017; Marcinek et al., 2024). Even if the precise mechanism remains incompletely defined, the epidemiological direction of association appears sufficiently robust to justify inclusion in a modern cardiovascular review.

3.4. Arrhythmias and atrial fibrillation

One of the most persistent concerns surrounding caffeine is whether it promotes atrial fibrillation or other clinically relevant arrhythmias. Earlier medical advice often recommended caffeine reduction in patients with palpitations. However, modern evidence has challenged the view that moderate habitual caffeine intake independently increases atrial fibrillation risk (Caldeira et al., 2013; Cheng et al., 2014; Surma et al., 2023).

Meta-analyses have found that caffeine exposure is not associated with increased atrial fibrillation incidence, and some large cohort studies suggest a neutral or modestly favorable association (Caldeira et al., 2013; Cheng et al., 2014). This is clinically important because it indicates that routine coffee intake at moderate levels is unlikely to be a major independent trigger of atrial fibrillation at the population level.

Several explanations have been proposed. Acute symptoms such as palpitations do not necessarily predict long-term disease risk. Habitual coffee users may develop tolerance to the autonomic effects of caffeine. In addition, coffee contains anti-inflammatory and antioxidant compounds that could influence the atrial substrate over time (Surma et al., 2023). Nevertheless, symptom-based individual advice remains appropriate because some patients clearly report sensitivity to caffeine, even if that sensitivity does not translate into increased long-term arrhythmia incidence.

3.5. Ventricular arrhythmias and electrophysiological risk

The literature on ventricular arrhythmias is less extensive than the literature on atrial fibrillation, but the available evidence does not strongly suggest that moderate caffeine intake is dangerous for most people. Reviews of experimental and clinical data indicate that ordinary dietary caffeine exposure does not consistently increase ventricular arrhythmia burden in routine populations (Surma et al., 2023; Voskoboinik et al., 2019). However, very high acute doses may increase sympathetic activation and alter intracellular calcium handling, thereby creating conditions that lower the threshold for ectopy or triggered activity (Voskoboinik et al., 2019).

This distinction between ordinary exposure and high-concentration stimulant use is important. Energy drinks, caffeine shots, and pre-workout products may deliver stimulant loads that are qualitatively different from those associated with traditional coffee intake. In susceptible individuals, such exposures may be associated with palpitations, ectopy, or electrocardiographic changes (Mandato et al., 2025; Voskoboinik et al., 2019).

3.6. Blood pressure and vascular effects

Caffeine can acutely increase blood pressure through antagonism of adenosine-mediated vasodilation and through enhancement of sympathetic tone (Voskoboinik et al., 2019). This acute pressor response is generally more obvious in caffeine-naive individuals or infrequent consumers. However, the longer-term significance of this effect is less straightforward. Habitual consumers often develop tolerance, such that the pressor effect becomes attenuated over time (Grosso et al., 2017; Poole et al., 2017).

Large observational studies and reviews do not consistently support a strong positive association between moderate coffee consumption and chronic hypertension. This apparent paradox may reflect adaptation, measurement imprecision, and the influence of non-caffeine coffee constituents. Thus, while caffeine is not irrelevant to blood pressure management, moderate habitual coffee intake does not appear to be

a dominant independent driver of long-term hypertension risk in the general population (Grosso et al., 2017; Palatini et al., 2009; Poole et al., 2017).

Vascular function may also be influenced by coffee and caffeine in ways that are not uniformly adverse. Some intervention studies have reported improved endothelial function after acute caffeine ingestion, whereas others have produced mixed findings. The vascular response likely depends on baseline health status, dose, beverage composition, and timing of measurement (Shechter et al., 2011).

3.7. Endothelial function and related vascular biology

Endothelial function occupies an important conceptual space because it bridges mechanistic vascular effects and clinical cardiovascular outcomes. In selected studies, acute caffeine ingestion has improved endothelial function in subjects with and without coronary artery disease (Shechter et al., 2011). These findings argue against an exclusively harmful vascular profile for caffeine or coffee.

At the same time, the overall literature remains mixed. Some of this inconsistency may be explained by differences in population characteristics, study protocols, coffee composition, and dose. Coffee should not be viewed as a simple caffeine delivery system; it is a complex beverage with many biologically active compounds (Grosso et al., 2017; Poole et al., 2017). For this reason, conclusions about vascular effects should remain cautious and context sensitive.

3.8. Inflammation, oxidative stress, and related mechanisms

Inflammation and oxidative stress are central to atherosclerosis, endothelial dysfunction, and structural cardiac remodeling. Experimental studies suggest that caffeine may modulate inflammatory pathways, including NLRP3 inflammasome activity (Zhao et al., 2019). These findings offer a plausible mechanistic explanation for some favorable observational associations, especially when considered together with the antioxidant constituents of coffee (Grosso et al., 2017).

However, mechanistic promise should not be overstated. Much of the available evidence derives from cellular or preclinical models rather than direct cardiovascular outcome trials in humans. These pathways are useful for interpretation, but they are not substitutes for hard outcome data (Marcinek et al., 2024; Zhao et al., 2019).

3.9. Genetic and metabolic variability

One of the most clinically relevant sources of heterogeneity in caffeine response is genetic and metabolic variability. CYP1A2 is the principal enzyme responsible for caffeine metabolism, and genetic variation influences whether an individual is a relatively fast or slow metabolizer (Cornelis et al., 2006; Palatini et al., 2009). Studies have suggested that this variation may modify the relationship between coffee intake and outcomes such as myocardial infarction or hypertension (Cornelis et al., 2006; Palatini et al., 2009).

These findings are important because they help explain why caffeine may be broadly safe at the population level but poorly tolerated by some individuals. Slow metabolizers may experience longer exposure to circulating caffeine after a given dose and may therefore be more susceptible to prolonged sympathetic or hemodynamic effects. However, genetics is only one part of the story. Smoking, medication use, hormonal factors, pregnancy, liver function, and habitual exposure can all influence caffeine clearance and tolerance.

For practical purposes, the modern literature supports a personalized rather than universal approach to caffeine counseling. Product type, dose, timing, co-exposure, and patient symptoms should all be considered before translating population-level findings into individual recommendations.

3.10. Energy drinks and concentrated stimulant products

A major theme of recent cardiovascular literature is the need to distinguish coffee from energy drinks and concentrated caffeine products. Energy drinks often contain high caffeine doses delivered rapidly, together with sugar, taurine, guarana, and other active ingredients. This combination may affect cardiovascular risk in ways that differ substantially from ordinary coffee (Mandato et al., 2025; Voskoboinik et al., 2019).

Reviews of energy drinks report increases in blood pressure, heart rate, and QTc interval, with the latter finding especially relevant from an electrophysiological standpoint (Mandato et al., 2025; Voskoboinik et al., 2019). These products are also frequently consumed quickly, during exercise, sleep deprivation, alcohol co-ingestion, or high-stress states, all of which may amplify cardiovascular strain.

From a public health perspective, this distinction is critical. The relatively reassuring literature on moderate coffee intake should not be generalized to all caffeine-containing products. Product matrix, co-ingredients, consumer behavior, and rate of exposure all matter. For clinicians, this means that asking about coffee use is not enough; the type of caffeinated product and the pattern of use must also be considered.

3.11. Dose-response patterns and exposure assessment

A recurring theme across the literature is that cardiovascular risk cannot be understood without careful attention to dose. However, dose is often measured imperfectly. Many large prospective studies report coffee intake in cups per day rather than milligrams of caffeine, even though caffeine content varies substantially according to bean type, roasting, brewing method, serving size, and whether the beverage is filtered, espresso-based, instant, or commercially prepared (Grosso et al., 2017; Poole et al., 2017). This creates a major interpretive challenge because two individuals categorized as drinking three cups per day may differ greatly in true caffeine exposure.

In addition, cup-based measures do not capture caffeine from tea, cola beverages, chocolate products, energy drinks, pre-workout formulas, or over-the-counter stimulants. As a result, the same nominal category of coffee intake can reflect quite different pharmacological exposure profiles. Despite these measurement limitations, a broad dose-response pattern emerges. Low-to-moderate habitual intake is usually associated with neutral or favorable long-term outcomes, while very high acute doses are more commonly associated with adverse hemodynamic or electrophysiological responses (Mandato et al., 2025; Poole et al., 2017; Voskoboinik et al., 2019).

The literature often refers to approximately 200-400 mg of caffeine per day as a moderate intake range for healthy adults, though this range is better understood as a practical public-health benchmark than as a precise therapeutic threshold (Voskoboinik et al., 2019). It should also be emphasized that the meaning of a given dose depends on context. A 250 mg exposure consumed gradually over the morning in coffee is physiologically different from 250 mg ingested rapidly before exercise in an energy drink or powdered supplement.

This distinction is relevant not only biologically but also methodologically. Studies of coffee-drinking habits tend to capture slow, repeated, socially integrated use patterns. By contrast, high-risk exposures often involve bolus intake, polysubstance co-use, sleep deprivation, alcohol consumption, or strenuous physical activity (Mandato et al., 2025). Therefore, dose should not be conceptualized solely as quantity, but as a combination of amount, speed of administration, delivery matrix, and co-exposure environment.

Another challenge is the difference between acute and chronic endpoints. An acute increase in blood pressure or a transient sensation of palpitations does not automatically translate into a higher long-term risk of myocardial infarction, atrial fibrillation, or cardiovascular death. Conversely, favorable long-term associations in cohort studies do not prove that caffeine is directly protective in a pharmacological sense. This disconnect between short-term physiology and long-term epidemiology explains much of the apparent contradiction in the caffeine literature. The most defensible interpretation is that low-to-moderate habitual exposure is generally well tolerated in most adults, whereas acute high-dose exposure can become clinically meaningful in susceptible individuals or in high-risk situations.

3.12. Special populations and vulnerable groups

The cardiovascular safety of caffeine cannot be fully understood without considering special populations. Findings derived from generally healthy middle-aged adults do not automatically apply to adolescents, pregnant individuals, older adults with polypharmacy, or patients with established cardiovascular disease. These groups differ not only in baseline cardiovascular risk but also in pharmacokinetics, pharmacodynamics, and behavioral patterns of intake.

In adolescents and young adults, the rise of energy drinks has changed the exposure profile substantially. Younger consumers are more likely to ingest caffeine rapidly, combine it with alcohol, consume it before sports or examinations, and use products with poorly appreciated caffeine content (Mandato et al., 2025). In such settings, symptoms such as palpitations, anxiety, tremor, chest discomfort, and insomnia may occur even without structural heart disease. While serious cardiovascular events remain uncommon, concern is justified because this population often consumes caffeine in patterns that differ sharply from the habitual coffee-drinking model that underlies much of the reassuring epidemiology.

Pregnancy represents another important context. Caffeine clearance is reduced during pregnancy, especially in later trimesters, increasing the duration of exposure after a given dose. Although the main clinical concerns in pregnancy often relate to fetal outcomes rather than maternal arrhythmia or blood pressure alone, slower clearance remains relevant when counseling about intake. It also illustrates a broader principle: standard safe intake estimates derived from healthy non-pregnant adults should not be applied indiscriminately to all physiological states.

Older adults may present a different set of considerations. On the one hand, many older adults consume coffee habitually and tolerate it well; on the other hand, this population more often has hypertension, coronary artery disease, atrial arrhythmias, impaired sleep, or concurrent medication use that may modify caffeine metabolism (Palatini et al., 2009). The interaction between caffeine and prescribed drugs, including some psychotropics and hormonal therapies, may alter exposure substantially. Moreover, in patients with frailty, dehydration, or sleep fragmentation, even moderate caffeine consumption later in the day may indirectly worsen cardiovascular risk by impairing sleep or increasing sympathetic tone.

Patients with established cardiovascular disease also require more individualized interpretation. The literature does not support universal caffeine avoidance in all people with coronary disease, atrial fibrillation, or heart failure. Nonetheless, certain subgroups warrant caution: those with poorly controlled hypertension, known channelopathies, recurrent symptomatic palpitations clearly triggered by stimulants, severe anxiety associated with adrenergic symptoms, or a history of arrhythmic events related to energy drinks or supplement use (Surma et al., 2023; Voskoboinik et al., 2019). In such cases, individualized dose reduction or product avoidance may be more appropriate than broad population-based reassurance.

Finally, athletes and highly active individuals represent a special case because caffeine is often used intentionally for performance enhancement. Ergogenic benefits are well described in sports science, but cardiovascular interpretation must take into account exercise intensity, hydration status, ambient temperature, pre-existing structural heart disease, and concurrent stimulant ingredients (Mandato et al., 2025). A dose tolerated at rest may be less benign when combined with extreme exertion, heat stress, or dehydration. Therefore, special populations should be considered not as exceptions to the evidence but as crucial contexts in which the general evidence must be applied carefully.

4. Discussion

The literature reviewed here supports a balanced, dose-sensitive interpretation of caffeine and cardiovascular health. The most defensible overall conclusion is that moderate habitual intake, especially through traditional coffee consumption, is generally associated with a favorable or neutral long-term cardiovascular profile, whereas acute high-dose exposure is more likely to produce clinically relevant adverse effects (Chieng et al., 2022; Mandato et al., 2025; Poole et al., 2017). In practical terms, the same compound can be compatible with cardiovascular safety in one context and problematic in another. This is why caffeine should be discussed less as a fixed good-or-bad exposure and more as a context-dependent cardiovascular factor.

This perspective also helps correct an older clinical narrative that treated caffeine as a broadly dangerous stimulant for the heart. That view is not well aligned with current population-level evidence. The contemporary literature does not support routine avoidance of moderate coffee intake in the general population, and it does not show a consistent increase in atrial fibrillation risk with ordinary habitual consumption (Caldeira et al., 2013; Cheng et al., 2014). At the same time, newer findings should not be simplified into a claim that caffeine is universally protective. Much of the evidence is observational, and the apparent benefits may partly reflect broader dietary and behavioral patterns among coffee drinkers (Grosso et al., 2017; Poole et al., 2017).

A central interpretive issue is the difference between coffee and isolated caffeine. Coffee is a chemically complex beverage containing many biologically active compounds other than caffeine, including chlorogenic acids, diterpenes, and other polyphenols. These constituents may influence endothelial function, oxidative stress, inflammation, and metabolic regulation (Grosso et al., 2017; Marcinek et al., 2024). As a result, favorable associations observed in coffee studies cannot automatically be attributed to caffeine alone. This distinction matters because the public often treats evidence about coffee, caffeine tablets, and caffeinated energy products as though all three were interchangeable, even though their biological and behavioral profiles differ substantially.

The distinction between habitual and acute exposure deserves equal emphasis. A person who drinks two or three cups of coffee per day over many years is not physiologically equivalent to someone who rapidly consumes a large energy drink, a pre-workout formulation, or multiple stimulant products within a short time. Rate of exposure, total dose, co-ingredients, and background tolerance all shape cardiovascular response (Mandato et al., 2025; Voskoboinik et al., 2019). This helps explain why the long-term coffee literature is relatively reassuring while the literature on energy drinks more often highlights blood pressure elevation, sympathetic overstimulation, and QTc-related concerns.

Interindividual variability further complicates interpretation. Genetics, especially CYP1A2-related variation, may influence caffeine clearance and prolong exposure in slower metabolizers (Cornelis et al., 2006;

Palatini et al., 2009). However, genotype is only one part of the picture. Medication interactions, smoking status, hormonal factors, pregnancy, anxiety sensitivity, sleep disruption, and baseline cardiovascular disease may all alter tolerance and perceived symptom burden. Therefore, a population-level conclusion of general safety does not eliminate the need for individualized clinical advice. Some patients clearly tolerate caffeine well, whereas others experience palpitations, tremor, blood pressure sensitivity, or sleep-related worsening at relatively modest doses.

Taken together, the evidence supports a practical middle position. Moderate caffeine intake, especially in the form of coffee, should not automatically be discouraged in healthy adults or in all cardiovascular patients. At the same time, clinicians should remain cautious about high-dose products, mixed stimulant formulations, and susceptible subgroups. In that sense, caffeine is best understood not as a single exposure with a single cardiovascular effect, but as a family of exposures whose risk profile emerges from dose, matrix, timing, and host susceptibility.

4.1. Why observational benefit should be interpreted carefully

An important methodological point is that many favorable findings in the coffee literature come from observational studies. These studies are valuable and often very large, but they cannot eliminate all residual confounding. Coffee consumption is associated with multiple behavioral, cultural, and socioeconomic variables that are difficult to fully adjust for. Health-conscious users may differ from non-users in ways that are only partially captured by statistical models. For that reason, the literature supports cautious language such as associated with rather than strong causal claims (Grosso et al., 2017; Poole et al., 2017).

Another limitation is exposure measurement. Many studies quantify intake in cups per day, which does not precisely represent true caffeine dose. Cup size, preparation method, roasting profile, brew strength, and product formulation can all change caffeine content substantially. Even when reported intake appears similar, actual pharmacological exposure may differ meaningfully across individuals and populations. This problem is especially relevant when attempting to compare traditional coffee with energy drinks, supplements, or other non-traditional caffeine sources (Poole et al., 2017; Voskoboinik et al., 2019).

4.2. Practical implications for patients and clinicians

For healthy adults, the current evidence supports the view that moderate habitual caffeine intake is generally safe (Poole et al., 2017; Surma et al., 2023). In clinical practice, however, the more useful questions are not abstract but concrete: what product is being used, in what dose, how quickly is it consumed, whether it is taken with alcohol, exercise, nicotine, or other stimulants, and whether the patient reports symptoms. This approach is more clinically meaningful than a simple recommendation to either permit or ban caffeine.

For patients who consume traditional coffee without symptoms, routine avoidance may not be necessary. By contrast, patients using energy drinks, caffeine powders, multi-ingredient pre-workout products, or repeated high-dose stimulant intake deserve more careful counseling (Mandato et al., 2025; Voskoboinik et al., 2019). The same is true for individuals with known arrhythmic syndromes, poorly controlled hypertension, severe anxiety sensitivity, or sleep-related vulnerability. In these groups, even if the epidemiological literature remains broadly reassuring at the population level, individualized caution is justified.

4.3. Coffee, isolated caffeine, and energy drinks are not interchangeable exposures

One of the most important conceptual errors in public discussion of caffeine is the tendency to treat coffee, isolated caffeine, and energy drinks as equivalent exposures. They are not. Coffee is typically consumed more slowly, in socially patterned doses, and within a matrix rich in non-caffeine compounds (Grosso et al., 2017; Poole et al., 2017). Energy drinks, by contrast, are often consumed rapidly and may include additional active ingredients as well as large amounts of sugar (Mandato et al., 2025). Isolated caffeine products may deliver highly concentrated doses without any buffering beverage context. Treating these exposures as interchangeable risks obscuring the very differences that are most important for cardiovascular safety.

4.4. Clinical counseling and patient-centered interpretation

The practical value of the caffeine literature depends on whether it can guide real clinical conversations. In many cases, patients ask simple questions, such as whether they should stop drinking coffee or whether caffeine is bad for the heart, but the evidence demands more nuanced answers. For asymptomatic healthy adults who consume moderate amounts of coffee, the current literature does not support routine advice to avoid caffeine for cardiovascular prevention (Poole et al., 2017; Surma et al., 2023). Reassurance is usually appropriate, especially when intake is stable, moderate, and not associated with symptoms.

In contrast, a symptom-based approach is often better for patients who report palpitations, anxiety, insomnia, blood pressure lability, or chest discomfort temporally related to caffeine use. In these situations, the question is not whether caffeine increases average population risk, but whether it is contributing to symptoms or physiological stress in a particular person. A short-term reduction trial may therefore be reasonable even if the general evidence on long-term outcomes is reassuring. This pragmatic approach aligns evidence with individualized care.

Counseling should also distinguish between reducing dose and changing product type. A patient who tolerates coffee poorly may not need to eliminate all caffeine but may benefit from smaller servings, slower consumption, avoiding late-day intake, or switching away from energy drinks and pre-workout products. In some cases, moving from highly concentrated stimulant products to traditional coffee may substantially reduce symptomatic burden even if overall caffeine exposure changes only modestly.

Patients with known cardiovascular disease often require tailored discussion rather than generic restriction. For example, a stable patient with well-controlled atrial fibrillation who drinks one or two cups of coffee daily without symptoms should not automatically be told that coffee is harmful. By contrast, a patient with recurrent stimulant-associated palpitations, poorly controlled hypertension, hypertrophic cardiomyopathy, or long-QT vulnerability may warrant more cautious advice, particularly regarding non-traditional products (Surma et al., 2023; Voskoboinik et al., 2019). The principle is to integrate population evidence with symptom history, underlying disease, medication profile, and patient preference.

Shared decision-making is especially important because caffeine has quality-of-life implications. Coffee and tea are embedded in social rituals, work performance, and personal routine. Overly restrictive advice can reduce adherence and trust if it is not clearly justified. A patient-centered approach therefore frames caffeine guidance not as moral prohibition but as risk calibration: identifying when current habits are probably acceptable, when moderation is sensible, and when avoidance of specific products is justified.

4.5. Public health, labeling, and regulatory implications

Beyond individual counseling, the caffeine literature has public-health implications. Because caffeine is ubiquitous, safety communication should distinguish clearly between ordinary dietary patterns and high-risk consumption models. Public misunderstanding often arises when headlines about coffee being good for the heart are interpreted as endorsement of any caffeinated product in any dose. This can be problematic in the era of energy drinks, powdered stimulants, and high-caffeine shots, where consumers may underestimate total dose and overestimate safety (Mandato et al., 2025; Voskoboinik et al., 2019).

A major regulatory issue is transparency of labeling. Many consumers do not know how much caffeine they ingest across multiple products in a single day. Coffeehouse beverages, energy drinks, supplements, and mixed stimulant products vary widely in caffeine content, and serving-size conventions are often confusing. Clearer labeling would improve consumer autonomy and reduce inadvertent excess intake, particularly in younger users and in people combining multiple caffeinated products.

Public-health messaging should also emphasize speed and context of intake rather than quantity alone. The same total daily dose may carry different risk depending on whether it is spread through the day or consumed quickly, whether it is paired with alcohol or strenuous exercise, and whether it occurs in a sleep-deprived individual (Mandato et al., 2025). Educational materials that focus only on a single daily milligram threshold may therefore miss clinically relevant aspects of exposure.

There is also a case for targeted education in schools, universities, gyms, and sports settings, where high-risk use patterns may be more common. Such education should avoid alarmism; most caffeine use does not lead to serious cardiovascular events. However, it should accurately communicate that energy drinks and concentrated stimulant products are not equivalent to ordinary coffee. This distinction could reduce the inappropriate carryover of reassuring coffee literature into contexts where the evidence is substantially less benign.

Finally, the public-health conversation should acknowledge uncertainty. Moderate caffeine use appears broadly safe for most healthy adults, but not every consumer experiences caffeine the same way. Regulatory and educational strategies should therefore support both population-wide safety standards and individualized recognition of intolerance or vulnerability.

4.6. Integrating mechanistic and epidemiological evidence

A frequent challenge in nutrition and cardiovascular science is reconciling mechanistic plausibility with epidemiological observation. Caffeine is a good example. Mechanistically, it can raise blood pressure acutely, stimulate the sympathetic nervous system, affect calcium handling, and alter adenosine-mediated electrophysiology (Marcinek et al., 2024; Voskoboinik et al., 2019). On first principles alone, one might predict that higher intake would consistently worsen cardiovascular outcomes. Yet population studies often show neutral or favorable associations with moderate habitual coffee consumption (Chieng et al., 2022; Poole et al., 2017). This apparent contradiction is not evidence that either the mechanistic or epidemiological literature is wrong; rather, it suggests that net biological effects depend on duration, adaptation, exposure matrix, and competing pathways.

Several explanations are plausible. Acute laboratory effects may not persist in habituated users because of receptor adaptation and behavioral accommodation. Coffee's non-caffeine constituents may counterbalance or modulate some stimulant-related effects through antioxidant, anti-inflammatory, or metabolic pathways (Grosso et al., 2017; Marcinek et al., 2024). Confounding may also contribute, with coffee consumption acting as a marker of other lifestyle factors in some populations. The most balanced interpretation is therefore integrative: mechanistic evidence explains why high acute doses can be problematic, while epidemiological evidence suggests that ordinary habitual consumption in moderate amounts is not associated with the harm once assumed and may in some contexts correlate with benefit.

This integrative view is clinically useful because it discourages simplistic conclusions. It avoids the mistake of dismissing all concerns about caffeine merely because many cohort studies look reassuring, but it also avoids the opposite mistake of extrapolating acute laboratory effects into blanket dietary prohibitions. The evidence as a whole supports calibrated guidance rather than absolutism.

5. Limitations

Several limitations must be acknowledged. First, much of the evidence reviewed here is observational, which limits causal inference. Second, exposure measurement is often imprecise because cups per day do not standardize serving size, caffeine concentration, or co-ingredients (Poole et al., 2017). Third, many studies examine coffee rather than isolated caffeine, making mechanistic attribution difficult (Grosso et al., 2017). Fourth, the literature on energy drinks often includes heterogeneous products and smaller experimental studies, which complicates comparison (Mandato et al., 2025). Fifth, genetic and metabolic personalization remains promising but is not yet standardized for routine practice (Cornelis et al., 2006; Palatini et al., 2009).

Another limitation is that this review, although structured and systematic in approach, does not include a formal PRISMA flow diagram or a pooled quantitative synthesis. Its strength lies in balanced clinical interpretation rather than meta-analytic precision.

6. Future Directions

Several areas deserve further research. Better separation of coffee effects from isolated caffeine effects is needed, because the health implications of a complex beverage may differ substantially from those of a purified stimulant. Future studies should also improve dose standardization by measuring caffeine content more precisely and accounting for serving size, brewing method, and product formulation.

Energy drink research should pay closer attention to co-ingredients, rate of intake, exercise context, alcohol co-use, and age-related vulnerability (Mandato et al., 2025). Genotype-informed studies may help clarify whether CYP1A2 and related pathways are sufficiently predictive to support individualized recommendations (Cornelis et al., 2006; Palatini et al., 2009). There is also a need for stronger evidence in patients with pre-existing cardiovascular disease, where symptom-driven caution is common but direct evidence remains uneven.

Finally, future research should aim to link mechanistic observations involving endothelial signaling, autonomic regulation, calcium handling, and inflammatory pathways with clinically meaningful cardiovascular endpoints. This would improve translation from biological insight to patient care.

6.1. Priority research questions

Future research should address several unresolved questions that limit present-day interpretation. First, more studies should directly compare coffee, isolated caffeine, and multi-ingredient energy products using harmonized exposure metrics. Without this distinction, the field risks continuing to mix biologically different exposures into overly broad conclusions. Second, high-quality prospective studies in adolescents, athletes, pregnant individuals, and patients with established cardiovascular disease are needed, because these groups often dominate real-world counseling scenarios but remain underrepresented in population-wide inference.

Third, researchers should improve exposure assessment by moving beyond simple cup counting. Incorporating product-specific caffeine estimates, timing of consumption, and biomarker-supported exposure estimates could make dose-response analyses more clinically meaningful. Fourth, genotype-informed studies should clarify whether CYP1A2 and related markers can reliably identify people who would benefit from tailored intake recommendations. Finally, studies linking mechanistic intermediates, such as endothelial function, inflammatory signaling, autonomic markers, and electrophysiological parameters, to hard cardiovascular endpoints would help bridge the gap between bench research and preventive cardiology practice.

7. Conclusions

Current evidence indicates that the cardiovascular effects of caffeine are best understood as dose dependent, product dependent, and modified by individual susceptibility. Moderate habitual intake, especially through traditional coffee consumption, is generally associated with a favorable or neutral cardiovascular profile, including lower cardiovascular and all-cause mortality in observational studies and no clear increase in atrial fibrillation risk in the general population (Caldeira et al., 2013; Chieng et al., 2022; Poole et al., 2017). By contrast, acute high-dose exposure, particularly from energy drinks and concentrated stimulant products, is more consistently associated with adverse hemodynamic and electrophysiological effects (Mandato et al., 2025; Voskoboinik et al., 2019).

Accordingly, caffeine should not be described as either uniformly cardioprotective or uniformly cardiotoxic. Its real-world impact depends on amount, formulation, pattern of use, and host factors such as tolerance, comorbidity, and metabolism. The most defensible clinical message is that moderate intake appears safe for most healthy adults, while high-dose products and susceptible populations require a more cautious and individualized approach.

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REFERENCES

1. Caldeira, D., Martins, C., Alves, L. B., Pereira, H., Ferreira, J. J., & Costa, J. (2013). Caffeine does not increase the risk of atrial fibrillation: A systematic review and meta-analysis of observational studies. *Heart, 99*(19), 1383–1389. https://doi.org/10.1136/heartjnl-2013-303950
2. Cheng, M., Hu, Z., Lu, X., Huang, J., & Gu, D. (2014). Caffeine intake and atrial fibrillation incidence: Dose-response meta-analysis of prospective cohort studies. *Canadian Journal of Cardiology, 30*(4), 448–454. https://doi.org/10.1016/j.cjca.2014.01.026
3. Chieng, D., Canovas, R., Segan, L., Sugumar, H., Voskoboinik, A., Prabhu, S., Ling, L.-H., Lee, G., Morton, J. B., Kaye, D. M., Kalman, J. M., & Kistler, P. M. (2022). The impact of coffee subtypes on incident cardiovascular disease, arrhythmias, and mortality: Long-term outcomes from the UK Biobank. *European Journal of Preventive Cardiology, 29*(17), 2240–2249. https://doi.org/10.1093/eurjpc/zwac189
4. Cornelis, M. C., El-Sohemy, A., Kabagambe, E. K., & Campos, H. (2006). Coffee, CYP1A2 genotype, and risk of myocardial infarction. *JAMA, 295*(10), 1135–1141. https://doi.org/10.1001/jama.295.10.1135
5. Grosso, G., Godos, J., Galvano, F., & Giovannucci, E. L. (2017). Coffee, caffeine, and health outcomes: An umbrella review. *Annual Review of Nutrition, 37*, 131–156. https://doi.org/10.1146/annurev-nutr-071816-064941
6. Hamad, A. K. S. (2024). Caffeine and arrhythmias: A critical analysis of cardiovascular responses and arrhythmia susceptibility. *Journal of the Saudi Heart Association, 36*(4), 335–348. https://doi.org/10.37616/2212-5043.1402
7. Mandato, J., Kola, R., Tyson, T., Laffin, L., & Bales, R. (2025). The effects of energy drinks on the cardiovascular system: A systematic review. *Current Cardiology Reports, 27*(1), 156. https://doi.org/10.1007/s11886-025-02293-w
8. Marcinek, K., Luzak, B., & Rozalski, M. (2024). The effects of caffeine on blood platelets and the cardiovascular system through adenosine receptors. *International Journal of Molecular Sciences, 25*(16), 8905. https://doi.org/10.3390/ijms25168905
9. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, Article n71. https://doi.org/10.1136/bmj.n71
10. Palatini, P., Ceolotto, G., Ragazzo, F., Dorigatti, F., Saladini, F., Papparella, I., Mos, L., Zanata, G., & Santonastaso, M. (2009). CYP1A2 genotype modifies the association between coffee intake and the risk of hypertension. *Journal of Hypertension, 27*(8), 1594–1601. https://doi.org/10.1097/HJH.0b013e32832ba850
11. Poole, R., Kennedy, O. J., Roderick, P., Fallowfield, J. A., Hayes, P. C., & Parkes, J. (2017). Coffee consumption and health: Umbrella review of meta-analyses of multiple health outcomes. *BMJ, 359*, Article j5024. https://doi.org/10.1136/bmj.j5024
12. Shechter, M., Shalmon, G., Scheinowitz, M., Koren-Morag, N., Feinberg, M. S., Harats, D., Sela, B. A., Sharabi, Y., & Chouraqui, P. (2011). Impact of acute caffeine ingestion on endothelial function in subjects with and without coronary artery disease. *The American Journal of Cardiology, 107*(9), 1255–1261. https://doi.org/10.1016/j.amjcard.2010.12.035
13. Stevens, L. M., Linstead, E., Hall, J. L., & Kao, D. P. (2021). Association between coffee intake and incident heart failure risk: A machine learning analysis of the Framingham Heart Study, the ARIC Study, and the CHS. *Circulation: Heart Failure, 14*(2), Article e006799. https://doi.org/10.1161/CIRCHEARTFAILURE.119.006799
14. Surma, S., Romańczyk, M., Filipiak, K. J., & Lip, G. Y. H. (2023). Coffee and cardiac arrhythmias: Update review of the literature and clinical studies. *Cardiology Journal, 30*(4), 654–667. https://doi.org/10.5603/CJ.a2022.0076
15. Voskoboinik, A., Koh, Y., & Kistler, P. M. (2019). Cardiovascular effects of caffeinated beverages. *Trends in Cardiovascular Medicine, 29*(6), 345–350. https://doi.org/10.1016/j.tcm.2018.09.019
16. Zhao, W., Ma, L., Cai, C., & Gong, X. (2019). Caffeine inhibits NLRP3 inflammasome activation by suppressing MAPK/NF-κB signaling and A2aR signaling in LPS-induced THP-1 macrophages. *International Journal of Biological Sciences, 15*(8), 1571–1581. https://doi.org/10.7150/ijbs.34211