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An Overview of the Risks of Contemporary Energy Drink Consumption and Their Active Ingredients on Cardiovascular Events

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Abstract

Purpose of Review From the introduction of the popular energy drink "Red Bull" in 1997 to the United States, energy drink consumption has rapidly grown and evolved. In the last decade, in particular, these beverages have been considered a potential health hazard. This is due to their large concentrations of caffeine in addition to other components such as taurine, B vitamins, guarana, L-carnitine, and ginseng that have individual risk as well as potential synergistic risk with other ingredients.

Recent Findings This review focuses on the evolving market of energy, typical "active" components of the most used drinks, and their potential effects on health, particularly cardiovascular risk. The most often consumed products are analyzed for their caffeine content and by their key active ingredients. These ingredients are then considered based upon their potential for cardiac risk alone and in combination with others.

Summary When used within the recommended dosage, all these components of energy drinks have no to very rare reported adverse health impacts. However, intoxication can occur upon prolonged and excessive consumption of energy drinks and in with consumption of other products. Furthermore, potential vulnerable populations (ex., youth, pregnant women, and those with cardiovascular conditions) should limit consumption of energy drinks, pending further research.

Keywords Energy drinks · Cardiovascular risk · Atrial fibrillation · Taurine · Guarana · L-Carnitine caffeine

Introduction

Energy drink consumption is on the rise. The energy drink market was estimated at 8.25 billion US dollars in 2018 and is projected to increase to 10.91 billion by 2023 in the USA [1].

With the rise in consumption that is increasing worldwide, there has been an increase in reported cases of intoxication leading to cardiovascular events, including arrhythmias and seizures. Along with the rise in consumption, there has been a rise in emergency room visits attributed to energy drink consumption. The Substance Abuse and Mental Health Services Administration has reported that emergency room visits associated with energy drink consumption have doubled from 10,068 visits in 2007 to 20,783 visits in 2011 [2]. Of this 206% increase, more emergency room visits were observed in 18–39-year-old males than any other demographic. The consumption of energy drinks has become a public health concern as a growing body of evidence documents various harmful effects these drinks have incurred.

Although "energy drinks" have existed since the 1960s, the introduction of "Red Bull" in the United States in 1997 sparked the growing trend in consumption. Since this initial introduction, over 500 new energy drinks have been launched worldwide, some of the most prominent being Red Bull, Monster, and Rockstar, making up over 80% of the industry in 2006. [3] These drinks vary widely in caffeine content, ranging from 50 to 505 mg per container. [4] While the principal ingredient in energy drinks is caffeine, other common substances include in isolation and combinations that include taurine, B complex vitamins, guarana, L-carnitine, and ginseng. [5] The acute and chronic effects resulting from excessive consumption

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of these beverages are still not fully known and pose a potential for adverse health consequences that should be considered and may be cause for regulatory action. In addition, it is unknown if these different substances and ingredients may synergistically impact inherent risks.

This updated review was undertaken in a rapidly evolving marketplace of energy drinks to explore the current trends with respect to energy drinks and their components, to evaluate evidence surrounding adverse health impacts (in particular cardiovascular events), and to offer potential management strategies.

The Current Situation Surrounding Energy Drinks

Energy drinks are marketed broadly to promote energy as well as mental and physical endurance and performance. According to the National Center for Complementary and Integrative Health (NCCIH), energy drinks have been found to improve physical endurance in some cases. However, there is less support for impacts on muscle strength. Energy drinks often contain high levels of caffeine and may also include other enhancing additives, such as sugar, taurine, carnitine, B vitamins, and guarana, a plant product containing concentrated caffeine. [6] Energy drinks can be classified as dietary supplements and are the second most popular supplement for men between 18 and 34 years old. Likewise, energy supplements are commonly used among teenagers (12–17 years), with nearly one-third reporting use in this demographic. [7, 8]

There are two kinds of energy drinks, energy shots that are generally 2–2.5 oz in size and energy drinks that are generally 8–16 oz in size. Energy shots are concentrated liquid and contain approximately 113–200 mg of caffeine. Energy drinks (8–16 oz) contain approximately 50–500 mg of caffeine. [4] As noted, the amount of caffeine can vary widely between energy drinks, and the exact amount of caffeine in a given product may not be easy to identify. This extreme variety may be partly because there is no requirement to report the amount of caffeine in these products. For comparison purposes, the caffeine contained in a cup (8 oz) of coffee is approximately 100 mg, and a bottle of cola (12 oz) is 35 mg. [9, 10] While caffeine is a significant component of energy drinks and has raised safety concerns, other components previously mentioned have also begun to be controversial and raise concerns.

Common Potential Stimulants in Energy Drinks

Caffeine

Caffeine, a methylxanthine, is a naturally occurring mild stimulant that has often been touted as an energy enhancer through increased sympathetic nerve activity. Caffeine can produce a subjective reinforcing and discriminative stimulus similar to those produced through dopamine by cocaine and amphetamines. [11] Upon consumption, caffeine rapidly absorbs in the body, reaching peak plasma levels within 30 min of consumption. [12] At high doses, caffeine can disseminate throughout the body passing through the blood–brain barrier and the placenta in pregnant women increasing risk for low birth weight infants and spontaneous abortion. [13•, 14•] The US Food and Drug Administration (FDA) considers up to 400 mg of caffeine a safe amount for adults and 200 mg for pregnant women. [15] While the FDA has not set guidelines for safe consumption in children, the Canadian government recommends the following limits: ages 4–6: 45 mg, ages 7–9: 62 mg, and ages 10–12: 85 mg. In adults, high doses (> 400 mg) of caffeine can lead to increased anxiety, nausea, jitters, and nervousness. [16] These adverse effects were also observed in children at lower doses (100–400 mg). [17•]

Caffeine acts as a competitive phosphodiesterase inhibitor, leading to an increase in cyclic AMP and, consequently, positive inotropic action on the myocardium raising cardiac output and blood pressure. [18] Evidence suggests that energy drinks may improve reaction time and physical performance by attenuating the decrease in skill performance caused by sleep deprivation. [19] Furthermore, it has been reported that caffeine may act as a natural antioxidant by preventing oxidative stress. This effect can improve physical performance and may serve as a protectant against cardiovascular damage and help prevent cancer. That being said, there is little evidence to suggest that caffeine alone contributes to decreased cancer risk due to similar results reported in other compounds that act as antioxidants. [12]

Taurine

Taurine is a conditionally essential amino acid. It is one of the highest concentrated free amino acids in the human body and accounts for 0.1% of the human body weight, with most of the amino acid being located in the leukocytes, heart, muscle, retina, kidney, bone, and brain. [20] This is due to its role in modulating contractile function. Taurine increases force generation within the muscle by enhancing the sarcoplasmic reticulum's calcium accumulation and release. It is theorized that muscle fibers may modulate their contractility by modifying taurine levels in response to neural stimuli. [21] Taurine deficiency has been associated with a decreased sensitivity of cardiac muscle to $Ca2+$ decreasing inotropic capability. This finding has led to the argument that taurine supplementation may improve physical performance by increasing blood supply to organs, especially the musculoskeletal system. [22•].

Taurine is a principal ingredient in many energy drinks and caffeinated beverages (Table 2). When combined with caffeine, taurine displays a synergistic effect that increases athletic and mental performance consume. [22•] The European Commission of Health and Food Safety suggests that the consumption of taurine in humans, on average, ranges from 40 to 400 mg/day. [23] Studies suggest frequent consumption of taurine at concentrations above 400 mg/d results in taurine accumulation in the plasma. It also leads to slight increases in whole blood taurine levels. [24] Nevertheless, studies at this time have found no side effects from excessive intake of taurine, although there is a likely upper bound in which these may become manifest. By contrast, in the case of taurine deficiency, retinal abnormalities and decreased cardiac inotropic capability may occur. [25, 26]

B Complex Vitamins

B vitamins (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine hydrochloride, biotin, inositol, and cyanocobalamine) are often found in large quantities in energy drinks and in higher concentration than the recommended daily intake. B vitamins serve as coenzymes for cellular and mitochondrial function, including energy production, which has led some to believe B vitamins may increase energy expenditure. [27] A study in 2019 found that the excessive consumption of B vitamins is not metabolically inert. Instead, it resulted in a 24% increase in insulin secretion, differential hormone secretion, and elevated one-carbon flux to process the load placed by the vitamins. [28]

Guarana

Guarana has a high-caffeine content. The amount of caffeine in its seeds ranges from 2.3 to 7.8%. [29] The amount of caffeine is higher in guarana seeds compared to coffee beans, which contain 1 to 2%. [30]

The FDA generally recognizes guarana as safe, but they have not determined the amount considered safe to consume. [31] Because of this, the amount of caffeine in products containing guarana can be assumed to be larger than listed. For example, in a recent study, the authors noted that an energy drink containing guarana reported the caffeine concentration as 19.5 mg/100 mL. [32••] However, after the authors performed a chemical analysis on this energy drink, they found the caffeine concentration to be higher at 27.42 mg/100 mL, an increase of 40.62% from the reported value. Out of the 50 energy drinks evaluated in this study, only three were found to have caffeine concentrations within 2 mg of the reported values. [32••] Several of these drinks were found to have caffeine concentrations more than double their reported values.

L-Carnitine

L-Carnitine, a naturally occurring amino acid, is primarily manufactured by the liver and kidneys. It has a role in B-oxidation as a carnitine-dependent transporter of fatty acids, impacting metabolism and energy production. [18] The cellular uptake of L-carnitine occurs by stimulation of hematopoiesis, inhibition of collage-induced platelet aggregation, and prevention of programmed cell death in immune cells. [33] As a result, L-carnitine has shown promise for its use in training, competition, and recovery during times of strenuous physical activity.

While supplementation at safe doses may be beneficial during strenuous activity, high doses of L-carnitine may lead to increased platelet aggregation in patients with sarcopenia and thromboembolic phenomena. [34, 35] In addition, L-carnitine has been found to accelerate atherosclerosis via trimethylamine conversion to trimethylamine-N-oxide in a mice model. [36]

Ginseng

Asian ginseng reduces lactic acid metabolism, which has been shown to enhance physical endurance. [37] This finding may be attributed to ginseng extract that has a direct vasodilatory effect on blood vessels. Furthermore, ginseng extract is currently being investigated as a potential treatment for hypertension. [38] The vasodilatory effect of ginseng is due to its regulation of calcium and nitric oxide pathways. [39]

The recommended dose for ginseng is about 3 g/ day (Lee et al., 2012). The maximum dose considered safe is 9 g/day. [40] It has been found that individuals consuming 15 g of ginseng per day over prolonged periods of time can develop "ginseng abuse syndrome" characterized by depersonalization and confusion. [41] In a separate case study, a woman who consumed 25 g of ginseng per day reported nausea, vomiting, and cerebral arteritis. [42] Given the broad use of ginseng, it should be noted, however, that negative outcomes from prolonged and/or excessive ginseng consumption is generally considered low risk. [40] Nevertheless, more research on ginseng consumption is needed to establish safe use practices.

Energy Drink Sales

Sales of energy drinks have grown around 5% every year since 2013, within the 8–16-oz variety of energy drinks listed in Table 1. [43] Red Bull leads the Market with $2891 million in sales, followed by Monster Energy with $1763 million in sales.

Table 2 shows the top brands with their associated concentrations of caffeine followed by the next active ingredients used to enhance the energy drink.

Potential Cardiovascular Risk with Contemporary Common Energy Drink Ingredients

Caffeine

It is widely thought that caffeine, particularly at high concentrations, is associated with multiple cardiac risks such as palpitations, atrial fibrillation, and supraventricular and ventricular ectopy. These multiple conditions are thought to be caused by caffeine's effect of acutely raising blood pressure. This elevation in blood pressure has been shown to be more prominent in the elderly and those with underlying hypertension. Although these demographics have more prominent symptoms, one study found that ingestion of a 355 mL can of Red Bull in young adults increased systolic BP by approximately 10 mmHg, diastolic BP by approximately 7 mmHg, and heart rate by 20 beats/min. [44] These effects can be exacerbated by the average 4–6 h half-life of caffeine, creating ample opportunity for further intake of energy drinks with dose augmentation. [45, 46]

A comparative epidemiologic study of 347,077 patients in the UK Biobanks showed a slight increase in risk of general cardiovascular disease in patients with habitual, heavy coffee consumption compared to those drinking 1–2 cups per day. In this analysis, drinking > 6 cups per day increased risk by 22%, which was also increased by 11% in nondrinkers, and 7% in those that drank decaffeinated coffee; this association was unaffected by genetic variants influencing caffeine metabolism. [47]

However, there are also well-documented benefits to caffeine consumption as it has been reported to lower the risk for obesity, a cardioprotective measure. This association was found in an upward curve, with higher doses of caffeine increasing heart failure and low/normal doses proving beneficial. [48] There is some evidence that coffee metabolism can aid weight loss, lowering obesity rates and risk of cardiovascular disease. However, genetics, age, sex, liver function, and medication can influence absorption rates. This range in absorption rates is due to the fact that the effects of caffeine in coffee vary. There is minimal evidence that caffeine derived from sources other than coffee is effective in reducing the incidence of obesity, implying the possibility that other components of coffee are responsible for this correlation.

Next to alcohol, caffeine is one of the most commonly reported triggers of palpitations and atrial fibrillation. In a study of 1295 patients with atrial fibrillation, 28% reported caffeine was a trigger. [49••] However, there is a divergence in risk when objective measurements are used to link caffeine consumption and arrhythmia risk compared to patient-reported risk. For example, the female sex, Hispanic ethnicity, obstructive sleep apnea, and those with a family history of atrial fibrillation were associated with greater triggers. As these risk factors, Hispanic ethnicity seems to be at the greatest risk. [49••] An example of divergent risk was observed in another study using the UK Biobanks involving 386,258 habitual coffee consumption as previously defined was associated with a 3% lower risk of clinical atrial fibrillation and flutter. This benefit persisted in consideration of 7 common polymorphisms of hepatic caffeine metabolism. [50••]

In regard to ventricular arrhythmias, in a small study of 22 patients that ingested 275 mg of caffeine in coffee,

Table 1 Size, sales, and percent change of top five energy drinks in the United States of America as of 2021. Retrieved from Top Selling Energy Drink Brands [43]

Brand	Size (Fl oz)	Sales (US dollars)	Change (year on year)
Red Bull	8.46	3,259,914,735	16.0%
Monster Energy	16	3,236,278,049	12.6%
Bang Energy	16	1,205,452,872	6.6%
Red Bull Sugarfree	8.46	876,604,370	1.7%
Red Bull Editions	8.46	594,059,197	111.7%

Table 2 Caffeine concentration and active ingredients contained in the top five energy drinks in the United States of America as of 2021. Retrieved from Top Selling Energy Drink Brands [43]

Brand	Caffeine	First "active" ingredient	Second "active" ingredient	Third "active" ingredient	Fourth "active" ingredient	Fifth "active" ingredient
Red Bull	80 mg	Taurine	Caffeine	Niacinamide	Pyridoxine HCL	Vitamin B12
Monster Energy	160 mg	Taurine	Panax ginseng	L-Carnitine	Caffeine	Guarana
Bang Energy	300 mg	Caffeine	Essential amino acids	Creatyl-L-leucine	Niacinamide	Pyrodoxine
Red Bull Sugarfree	80 mg	Taurine	Caffeine	Niacinamide	Pyridoxine HCL	Vitamin B12
Red Bull Editions	80 mg	Taurine	Caffeine	Niacinamide	Pyridoxine HCL	Vitamin B12

there was no observed increased in risk towards ventricular arrhythmias during an electrophysiology study. [51••] In support of this observation, in a study of 1388 participants, it was found that there was no relationship observed between premature ventricular contractions and premature atrial contractions with moderate caffeine usage (< 275 mg). [52] These studies suggest with at least moderate consumption there is not a clear arrhythmia risk with caffeine and the discrepancy of these outcomes with those in which patients report caffeine is a common trigger of arrhythmia requires additional study. It is possible that some of this discrepancy is influenced by how caffeine impacts sleep quantity and quality.

Regarding potentially toxic doses (> 400 mg) of caffeine have been documented to affect the conductance and refractoriness of the heart leading to arrhythmia, in particular, delayed afterdepolarizations through the release of calcium from the sarcoplasmic reticulum. [53] A systematic review of various case studies reported arrhythmias, coronary vasospasm, aortic aneurysm dissection, cardiac arrest, QT prolongation, acute coronary thrombosis, and ST-elevation myocardial infarction related to energy drink consumption. [54] Among those with negative cardiovascular outcomes, 35% were related to arrhythmia.

Taurine

Congestive Heart Failure

Taurine has been approved for the treatment of congestive heart failure in Japan. [55, 56] The primary therapeutic benefit of taurine is through the reduction in the action of norepinephrine and angiotensin II, both of which decrease myocardial performance through elevation in afterload pressure, ventricular remodeling, and fluid remodeling. [57] Additionally, there is evidence to support the idea that taurine elevates high energy phosphate content in the heart, an additional determinant of mortality among patients suffering from congestive heart failure. [56] It should be noted that in one study by Huxtable and Bressler, taurine was found in higher concentration in the left ventricle of patients who died of congestive heart failure compared to those who died of other causes with no cardiovascular history. [58] This may suggest that taurine may have a negative inotropic effect. However, more recent research has shown the opposite, with taurine exerting a mild positive inotropic effect on the hyperdynamic heart as well as promotion of natriuresis and diuresis. [57]

Hypertension

Supplementation with taurine has been noted in the reduction of blood pressure and hypertension risk. This process appears to be mediated by a combination of diminished calcium concentrations, oxidative stress, sympathetic activity, inflammatory activity, and improvement in renal function through the promotion of diuresis. [59] It has been suggested that the dietary intake of taurine likely prevents the progression of cardiovascular diseases by repairing impaired endothelial function. Taurine supplementation has also been shown to significantly reduce blood pressure and improve vascular function in prehypertensive individuals, particularly those with high-normal blood pressure. [60]

Synergistic Effect of Taurine and Caffeine

A double-blind study performed by Baum and Weiss [61] examined the cardiovascular impact of the consumption of beverages containing both taurine and caffeine. It was found that cardiac contractility, particularly of the left atrial contractility post-exercise, was increased. These findings provide support for improved maximal performance and lower heart rate at submaximal working intensity as observed in previous studies. [61] Moreover, taurine potentially reduces the cardiovascular effects of caffeine. [59]

In a study of 50 volunteers, it was found that following consumption of high-caffeine energy drink (250-mL sugar-free energy drink containing caffeine (80 mg), taurine (1000 mg), and glucouronolactone (600 mg), or 250 mL carbonated water (control), there was a significant increase in platelet aggregation compared to the control ($13.7 \pm 3.7\%$ vs. $0.3 \pm 0.8\%$). When alcohol was mixed with the energy drink, the findings were exacerbated. In multiple case studies, sudden cardiac death, coronary vasospasm, and coronary thrombosis have been documented 1–2 h after consuming energy drinks mixed with alcohol. [62•] It appears that mixing alcohol with energy drinks is more common among the college population. It has been reported that 51% of college students have consumed at least one energy drink per month, and of those consumers, 54% had mixed it with alcohol. [62•]

Due to the variability of the ingredients in energy drinks, it is difficult to know which component is responsible for increased platelet aggregation. In addition, the exact mechanism of this phenomenon is unknown. However, it appears that some ingredients may also have a cardioprotective effect. It has been found that consumption of taurine leads to reduced platelet aggregation by 30–70%, potentially acting as a protective measure. [63••] This raises the question, are energy drinks that do not contain taurine or insufficient quantities, such as Bang (Table 2), will be more prone to cause platelet aggregation and myocardial infarction risk? This is an area in with further research is critically warranted as ingredients are combined.

B Complex Vitamins

Cardiovascular Disease and Stroke Risk

An association has been found between high dietary intake of folate and pyridoxine hydrochloride leading to a reduction in cardiovascular and stroke risk. [64] On the contrary, another study found that when individuals were given supplemental folic acid, vitamin B12, and vitamin B6, to lower homocysteine there was an increased risk leading to questions surrounding combinations of B complex vitamins. [65] Mechanistically, the association of B complex vitamins and cardiovascular risk may be due to homocysteine. Homocysteine is a sulfhydryl-containing amino acid that may increase risk for developing atherosclerotic vascular disease. [66] B complex vitamins serve as a substrate for homocysteine metabolism, resulting in increased blood homocysteine levels when in low concentration, and a 20% total homocysteine reduction has been associated with a 7% decrease in cardiovascular events (cardiovascular death, myocardial infarction, stroke). [67]

Guarana

As previously discussed, guarana seeds contain much higher levels of caffeine compared to coffee beans. At very high levels, caffeine increases intracellular calcium concentration resulting in noradrenaline release and dopamine receptor sensitization. This pathway causes ventricular tachyarrhythmias, particularly at high doses. [46] Caffeine plasma concentrations of 15 mg/L or higher may lead to poisoning or, in rare cases, death. Caffeine plasma concentrations of 80–100 mg/L are considered lethal. [68] Such high levels were previously most commonly found in diet pills or in individuals who frequently consumed many types of caffeinated beverages. Moreover, the presence of guarana in energy drinks compounds the potential effect of caffeine. Due to the lack of regulation on guarana in energy drinks, the amount of guarana in such drinks ranges from 1.4 to 300 mg, potentially ingesting very high levels of caffeine.[18] Overdosing guarana results in irritability, insomnia, anxiety, restlessness, muscle twitching, rapid heartbeat, and diuresis. [69]

L-Carnitine

Cardiovascular Disease and Stroke Risk

A systematic review and meta-analysis of 13 controlled trials concluded that L-carnitine supplementation had been shown to reduce the risk for angina by 40% and ventricular arrhythmias by 65%. [70] It may also increase left ventricular ejection fraction and decrease left ventricular remodeling, as seen in a longitudinal study in which patients treated early post-acute myocardial infarction with L-carnitine resulted in smaller left ventricular volumes compared to the placebo group. In addition, the incidence of death and congestive heart failure after discharge was drastically reduced in the treatment group. [71••] It should be noted that although the amount of L-carnitine added to energy drinks may not be enough to cause toxic effects, L-carnitine in large doses can lead to seizures, nausea, vomiting, abdominal pain, and diarrhea. [7]

Atherosclerosis

Rather than directly impacting atherosclerosis risk, microflora metabolizing L-carnitine has led to increased cardiovascular risk. Microbiota-derived trimethylamine (TMA) and trimethylamine-N-oxide (TMAO) produced by microflora have been found to enhance cardiovascular risk by promoting atherosclerotic lesion development. [36, 72] Increasing evidence suggests a correlation between TMAO and atherosclerosis risk. This relationship, along with L-carnitine, could prove valuable as targets for therapeutic strategies to reduce risk. However, TMAO has been found to promote platelet aggregation and consequent thrombus formation through the augmented release of calcium from intracellular reserves. [73] Further research is needed to evaluate the relationship between L-carnitine, TMA, TMAO, and platelet aggregation on the microbiome level, which may provide an explanation for the increase in platelet aggregation following the consumption of energy drinks. [74]

Ginseng

Long-QT Syndrome

Ginseng is well known for its adaptogenic effect mediated by compounds known as ginsenosides. The intake of 250 mg of ginseng by healthy adults resulted in an increased QTc by 0.015 s. [75] Although statistically significant, this result is not clinically significant for the average adult. However, in susceptible groups with inherited cardiomyopathies, such as long-QT syndrome (LQTS), significant prolongation of the QT may developed such as what was seen in a case of a 13-year-old girl who presented with chest pain and palpitations upon consuming an energy drink with a QTc > 500 ms. [76] Similarly, a 22-year-old female who consumed six cans of energy drinks (80 mg caffeine) who experienced sudden cardiac death was found to have LQTS. [77] Similar amounts of caffeine in otherwise healthy adults have no noticeable effect on QTc. [78]

Hypertension

Rat models have found an increase in insulin sensitivity leading to weight loss and improved serum cholesterol with ginseng supplementation. [79] If such findings can be observed in human models, it could be argued that ginseng supplementation may be cardioprotective. Notwithstanding, the amount of ginseng in energy drinks is likely not enough to produce a beneficial effect. Likewise, the amount of ginseng commonly used in energy drinks is likely not sufficient to cause toxicity, as seen in high intakes of ginseng (> 15 g/day), which have led to "ginseng abuse syndrome" characterized by hypertension. [80]

Management

It is not surprising that energy drink consumption is on the rise. It appeals to most demographics due to expert marketing, the variety in product and flavor, and claim to provide more energy and vitality. However, many consumers are unaware of the difference between energy drinks, soft drinks, and sports drinks. This has led to increased caffeine consumption making caffeine the most commonly ingested psychoactive drug worldwide. The potency of the caffeine contained in energy drinks is heightened by its other ingredients, such as taurine, B vitamins, guarana, L-carnitine, and ginseng.

Examples of concern of mixing ingredients have been shared previously. Potential risks extend to people traditionally felt to be a low risk for cardiac disease. For example, atrial fibrillation is extremely rare in the pediatric population and most commonly occurs in association with structural heart disease. [81] The popularity of energy drinks in the pediatric and adolescent population has led to increased arrhythmogenic potential. Multiple case studies have documented adolescents experiencing atrial fibrillation/atrial tachycardia after consuming energy drinks. [82]

Although taurine and L-carnitine have shown to be cardioprotective, guarana and caffeine combined may lead to adverse health outcomes. When high levels of caffeine are consumed in cases where underlying cardiovascular disease is present, there is increased probability that significant decrease in perfusion may occur resulting in myocardial ischemia, infarction, and arrhythmias. [83] Examining the relationship between energy drink consumption and cardiovascular risk is necessary to prevent future cardiovascular events.

While energy drink consumption is generally considered safe, many do not understand what the potential risks associated with consumption and what could be considered safe consumption practices. Misinformation surrounding energy drinks can be negated by regulations requiring products to inform the consumer of side effects as well as warnings for children, adolescents, pregnant women, and those with existing cardiovascular conditions. In addition, energy drinks should be required to calculate the caffeine concentration of not only the added caffeine but also the amount of guarana it contains to better inform consumers of the actual concentration of caffeine.

Conclusion

Energy drinks and their components raise concerns about the short- and long-term risks for cardiovascular events as they evolve and continue to combine "active" ingredients. These concerns have increasingly led to a range of restrictions and recommendations for conception, and as well as stricter requirements for product labeling. The FDA has been actively investigating the impact of energy drinks, but, due to a lack of data, has only been effective at regulating limits on the amount of caffeine allowed per serving and mandatory labeling of caffeine content. Although the evidence for harm from energy drinks is incomplete, the potential for public health concern should elicit further research into the various components of energy drinks and their synergistic effects. Furthermore, vulnerable populations (ex., youth, pregnant women, and those with cardiovascular conditions) should limit the consumption of energy drinks, pending further research.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

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