PIWOWAR, Michalina, AGOPSOWICZ, Katarzyna, BLICHARZ, Katarzyna, ZDZIEBŁO, Piotr, SITKO, Maria, BIERNACKA, Martyna, STOLARCZYK, Dominika, BĄK, Aleksandra, MOJŻESZ, Piotr and BIERNACKI, Igor. Energy Drinks - the potential risk to the cardiovascular system. A Review. Journal of Education, Health and Sport. 2025;82:60510. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.82.60510
https://apcz.umk.pl/JEHS/article/view/60510

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 23.04.2025. Revised: 25.04.2025. Accepted: 25.06.2025. Published: 28.06.2025.

Energy Drinks - the potential risk to the cardiovascular system. A Review

Michalina Piwowar[1], Katarzyna Agopsowicz[2], Katarzyna Blicharz[3], Piotr Zdziebło[4],

Maria Sitko[5], Martyna Biernacka[6], Dominika Stolarczyk[7], Aleksandra Bąk[8],

Piotr Mojżesz[9], Igor Biernacki[10]

[1] Student, Medical University of Silesia, Faculty of Medical Sciences in Zabrze, plac Traugutta Street 2, 41-800 Zabrze, Poland.
https://orcid.org/0009-0005-1383-8392; piwowarmichalina@gmail.com

[2] Medical Dentistry Doctor, Medical University of Warsaw, Faculty of dentistry, Żwirki i Wigury 61, 02-091 Warszawa, Poland.
https://orcid.org/0009-0006-3609-6472; katarzyna.agopsowicz@gmail.com

[3] Student, Medical University of Silesia, Faculty of Medical Sciences in Zabrze, plac Traugutta Street 2, 41-800 Zabrze, Poland.
https://orcid.org/0009-0009-1414-819X; katarzynablichr@gmail.com

[4] Medical Dentistry Doctor, Medical University of Lublin, Faculty of dentistry,
al. Racławickie 1, 20-059 Lublin, Poland.
https://orcid.org/0009-0000-9291-8406; piotrzdzieblo@op.pl

[5] Student, Jagiellonian University Medical College, ul. Świętej Anny 12, 31-008 Kraków, Poland
https://orcid.org/0009-0009-2078-3755; maria.sitko32@gmail.com

[6] Student, Medical University of Warsaw, ul. Żwirki i Wigury 61, 02-091 Warszawa, Poland.
https://orcid.org/0009-0002-5362-6894; biernacka.martynaa@gmail.com

[7] Student, Jagiellonian University Medical College, ul. Świętej Anny 12, 31-008 Kraków, Poland
https://orcid.org/0009-0000-8142-1138; stolarczykdominika2e@gmail.com

[8] Student, Jagiellonian University Medical College, ul. Świętej Anny 12, 31-008 Kraków, Poland
https://orcid.org/0009-0005-3852-914X; aleksandra.bak411@gmail.com

[9] Medical Dentistry Doctor, Medical Univeristy of Silesia, Faculty of dentistry, Plac Akademicki 17
41-902 Bytom, Poland
https://orcid.org/0009-0001-0430-5042; mojzeszpiotr@gmail.com

[10]Student, Medical University of Lodz, al. Tadeusza Kościuszki 4, 90-419 Lodz, Poland;
https://orcid.org/0009-0009-7726-3494; iggorbiernacki@gmail.com

Abstract

Energy drinks are products that have gained popularity in recent years among people seeking a quick energy boost. The ingredients they contain are intended to reduce the feeling of fatigue, improve the body's performance and concentration. The consumption of energy drinks raises controversy due to their potential negative impact on health, particularly on the cardiovascular system. Thanks to the increased interest of scientists in this topic, many reports of cardiovascular events related to the consumption of energy drinks have been created. This article discusses the composition of energy drinks their association with arrhythmias, hypertension, myocardial infarction, and coronary vasospasm., as well as examples of adverse events that occurred after their consumption.While further research is necessary to fully understand the long-term cardiovascular outcomes, this review highlights the importance of public awareness and regulatory measures to mitigate potential health risks associated with energy drink use.

Keywords: Energy Drinks; Cardiovascular System; Caffeine; Taurine; Arrhythmias; Myocardial infraction

Introduction

Energy drinks first appeared on the market in 1960 in Europe and Asia [1]. Since then many new companies have been established to produce this type of products and the market is constantly growing. For example in the United States, from 2004 to 2009, the energy drink market has seen growth of more than 240% [2]. Initially, the main consumers of energy drinks were athletes, but as the products became more available, the group of consumers has expanded. Currently, energy drinks are used largely by young adults and teenagers and first consumption usually occurs prior to age 12 [31]. Studies show that energy drinks are consumed by 30 to 50% of teenagers and young adults [3]. There is growing controversy surrounding energy drinks, heightened recently by increasing reports of toxic effects—most alarmingly involving cardiac arrhythmias, such as atrial fibrillation, and central nervous system abnormalities, including seizures.[29]

Many energy drink producers rely on similar ingredients. According to the Food and Drug Administration (FDA), energy drinks (EDs) are "a class of products in liquid form that typically contains caffeine, with or without other added ingredients" [30]. The most common ingredients are caffeine, taurine, carnitine, glucuronolactone, guarana, herbal extracts and B vitamins [2,4]. Manufacturers mix different proportions of ingredients with different additives, thanks to which they gain different taste values, vitamin combinations, and energy levels.

Caffeine has a similar chemical structure to adenosine, which allows it to bind to its receptors The main effect of caffeine contained in energy drinks is to block adenosine receptors in the brain, which makes it harder to fall asleep. Additionally, caffeine increases the secretion of epinephrine, which may improve mental and physical performance [4,7]. What else, caffeine increases heart rate and blood pressure. Energy drinks contain 70 to 200 mg of caffeine per serving, while a cup of coffee contains 110 to 150 mg for drip coffee, 65 to 125 mg for percolated coffee, and 40 to 80 mg for instant drinks [5]. After consuming 200 mg of caffeine,

side effects such as insomnia, headaches, nervousness, nausea, tachycardia and arrhythmias may occur [5,7,8].

Taurine is an amino acid found in the human body mainly in the retina and skeletal and cardiac muscle . It is also a common component of the diet. Taurine affects neuromodulation, cell membrane stability and modulation of intracellular calcium levels [4]. Few adverse effects are attributed to the use of taurine, even at high doses, but there are reports of a link between the effects of energy drinks containing caffeine and taurine and the deaths of athletes in Europe [8].

Carnitine refers to a group of compounds—including L-carnitine, acetyl-L-carnitine, and propionyl-L-carnitine—that are derived from amino acids. It occurs naturally in a variety of foods and is also synthesized endogenously in the liver, kidneys, and brain from the amino acids lysine and methionine. Carnitine plays a crucial role in energy metabolism, functioning as an essential cofactor that facilitates the transport of long-chain fatty acids into the mitochondria, where they are oxidized to produce adenosine triphosphate (ATP), the body's primary energy source.[30]

Guarana (*Paullinia cupana*) is a plant originating from central Amazon region **[6]**. Many energy drinks contain guarana in combination with caffeine or separately [10]. 1 g of guarana corresponds to 40 mg of caffeine (a cup of medium strength coffee) in terms of its stimulating effect [10]. caffeine from guarana is released slower than the free compound, which is why it has a longer stimulating effect [4].

Glucoronolactone occurs naturally in the human body and is produced in the liver as a result of glucose metabolism. It participates in the removal of toxins, supporting the process of excreting metabolic products; releasing hormones and other substances and in the biosynthesis of vitamin C. It is thought to aid in preserving glycogen levels by blocking other compounds from using up the muscle's glycogen stores and that is why it is added to energy drinks [4,5,9].

B vitamins are a set of water-soluble vitamins that have key functions in the body, particularly in the nervous system, metabolism, and energy production. B vitamins are a component of many energy drinks. A typical can of 250 mL may contain 360% of the recommended daily allowance (RDA) of B6, 120% of B12, and 120% of B3 (niacin) [4]. It is claimed that a higher intake of B vitamins increases concentration, improves mental alertness and mood. because B vitamins are water-soluble, their excess is excreted in the urine. The usefulness of large amounts of B vitamins in energy drinks is not well rationalized [4,5,2].

Sugars also known as simple carbohydrates are one of the body's primary sources of energy. In energy drinks they are presented in processed form. Long term and excessive consumption of simple sugars leads to carbohydrate metabolism and metabolic disorders like obesity and insulin resistance as well as negatibe impact on the circulatory system[5].

The growing popularity of energy drinks has been accompanied by an increase in emergency department visits among young individuals experiencing a range of adverse health effects. Energy drinks have been associated with harmful impacts on various organ systems. These effects range from relatively mild symptoms—such as anxiety, gastrointestinal discomfort, dehydration, nervousness, and rapid heart rate—to more serious complications, including rhabdomyolysis, acute kidney injury (AKI), ventricular fibrillation, seizures, acute mania, and stroke. In some cases, energy drink consumption has even been linked to fatalities.[30]

The aim of this review is to summarize current evidence on the cardiovascular risks associated with energy drink consumption. Relevant publications were identified using PubMed and Google Scholar databases, covering the period from 2008 to 2024.

Discussion

Numerous studies and clinical case reports have explored the impact of energy drink (ED) consumption on cardiovascular function. The evidence consistently indicates that even short-term intake can negatively influence cardiovascular parameters. For example, one randomized controlled trial demonstrated a significant increase in systolic blood pressure one hour after consuming energy drinks (from 116.9 ± 10.4 to 120.7 ± 10.7 mmHg) [11]. Additionally there was observed a QTc prolongation (393.3 ± 20.6 to 400.8 ± 24.1 ms, $P < 0.01$) which indicates a risk of arrhythmia [11] . Another study found a 73.6% increase in norepinephrine levels after consuming an energy drink, compared with 30.9% in the placebo group [12] .

Elevated blood pressure has also been observed in younger populations. Oberhoffer FS et al examined the effects of a single, bodyweight -adjusted dose of an energy drink on 24-hour ambulatory blood pressure in healthy children and adolescents. The results showed that energy drink consumption significantly increased both 24-hour systolic and diastolic blood pressure compared to the placebo. Minors, particularly those with an increased cardiovascular morbidity, should be discouraged from drinking EDs. Potentially, chronic ED consumption might lead to greater cardiovascular risk. [21]

The study conducted by Svatikova A et al. involved 25 healthy participants (14 men, average age 29) to assess the cardiovascular and metabolic effects of an energy drink compared to a placebo. After consuming the energy drink, participants experienced significantly higher increases in systolic (6.2% vs 3.1%), diastolic (6.8% vs 0%), and mean arterial pressure (6.4% vs 1.0%) compared to placebo. Heart rate did not differ significantly between conditions. These acute hemodynamic and adrenergic changes may predispose to increased cardiovascular risk. This study was limited by a small sample size and the use of only one energy drink. [22]

García A et al. investigated the acute effects of different commercially available energy drinks on cardiovascular function, stress levels, and working memory in 80 healthy medical students (average age 21.45 years, 62.5% male). Participants were assessed before and after consuming either carbonated water (control) or one of three popular energy drinks (A,B and C) containing similar caffeine levels but different compositions. The results showed that systolic blood pressure significantly increased 30 minutes after consumption in groups A and C. Group B showed a smaller increase in systolic blood pressure after one hour, a rise in diastolic

pressure, and a shortening of the QTc interval. Heart rate increased in groups A and C. Salivary cortisol levels rose in group B, while anxiety levels (STAI scores) decreased in group C. These findings highlight that energy drinks can cause varied acute effects on cardiovascular parameters, stress responses, and cognitive performance, depending on their composition. Further research is needed to fully understand the short- and long-term health implications. Greater awareness is necessary, particularly among young consumers such as students, regarding the potential risks associated with energy drink consumption.[23]

Miles-Chan JL et al. investigated whether the cardiovascular effects of Red Bull (RB) are solely due to its caffeine and sugar content. In a randomized, placebo-controlled crossover trial with eight healthy young men, hemodynamic responses were measured continuously following the intake of RB, sugar-free RB (sfRB), caffeine in water, or placebo. While RB, sfRB, and caffeine all raised blood pressure by a similar amount (3–4 mmHg), only RB significantly increased heart rate, stroke volume, cardiac output, double product, and myocardial contractility, while reducing total peripheral resistance. In contrast, sfRB and caffeine increased total peripheral resistance without affecting cardiac parameters. These findings indicate that RB and caffeine produce similar blood pressure responses via different hemodynamic mechanisms—cardiac versus vascular. The additional ingredients in RB do not appear to modify these effects. [24]

The background for the randomized, double-masked, placebo-controlled, crossover study by Shah SA et al. was the association between energy drinks and an increase in emergency room visits and deaths. Scientists demonstrated that caffeinated energy drinks significantly prolong the QTc interval and raise both brachial and central blood pressure following acute exposure. Further investigation is warranted to determine whether an individual ingredient or a unique combination is responsible for the observed electrophysiological and hemodynamic changes. [20]

Conversely, a study conducted by Ragsdale, F. R. explored the effects of Red Bull® energy drink on cardiovascular and neurological functions in college students. In a double-blind trial comparing regular and low-calorie Red Bull® with matched placebos, no significant changes in cardiovascular function or blood glucose were observed in any of the 68 participants during a 2-hour observation period. However, a second experiment involving 21 participants (9 males, 12 females) who underwent a cold pressor test (CPT) before and after consuming Red Bull® revealed a significant increase in blood glucose levels. Male participants showed a rise in diastolic blood pressure during the CPT, which was mitigated after consuming Red Bull®. No such blood pressure changes were observed in female participants. Additionally, Red Bull® consumption significantly increased pain tolerance across all participants. These findings suggest that Red Bull® may reduce cardiovascular responses to stress and enhance pain tolerance. [25]

A growing body of case reports has also linked excessive ED consumption with serious cardiovascular events such as myocardial infraction. For example, one report described a patient who presented to the emergency department with chest pain that occurred four hours after consuming an energy drink. Coronary angiography revealed a complete occlusion of the left anterior descending (LAD) artery caused by a thrombus. This situation was linked to the consumption of energy drinks, which may lead to increased platelet aggregation and

endothelial dysfunction, promoting thrombus formation and increasing the risk of heart attack [13] . In a separate report, a case was described of a 25-year-old man who experienced a heart attack following a week of consuming between 7 and 9 energy drink cans each day. With each can containing around 200 mg of caffeine, his daily intake ranged from 1,400 to 1,800 mg—far surpassing the recommended maximum of 400 mg per day. The patient's ECG revealed ST-segment depression in the precordial leads V2–V6, and a troponin I level of 32.22 µg/ml was recorded, indicating the presence of acute coronary syndrome [14].

Solomin et al., in their case report, described a 26-year-old male who presented to the emergency department with chest pain after consuming large quantities of energy drinks (approximately 8–10 cans daily). His symptoms included chest pain radiating to the left arm and jaw, numbness in the left arm, nausea, and sweating. An ECG revealed ST-segment elevation, and cardiac catheterization showed a 100% occlusion of the left circumflex artery, which was treated with a drug-eluting stent. The patient denied illicit drug use but was a smoker and had an abnormal lipid profile. Following treatment, his condition stabilized, and he agreed to stop both smoking and consuming energy drinks. This case highlights a potential link between excessive energy drink consumption and acute coronary syndrome in young adults. [26]

Gharacholou SM et al. reported a case involving a 27-year-old man with no prior medical history presented with acute chest pain, shortness of breath, and diaphoresis, one hour after symptom onset. He had a history of tobacco use and frequent energy drink consumption (4–5 cans within 12 hours) but no known cardiovascular risk factors apart from a family history. ECG showed ST-segment elevation in the anterior leads, and elevated cardiac biomarkers confirmed an acute anterior STEMI. Urgent coronary angiography revealed normal coronary arteries without signs of obstruction. Echocardiography and cardiac MRI indicated apical akinesis and delayed gadolinium enhancement. Despite treatment with nitrates and calcium channel blockers, intermittent chest discomfort persisted. Functional coronary testing ruled out both macrovascular and microvascular dysfunction, suggesting coronary vasospasm possibly triggered by excessive energy drink intake. The patient was advised to discontinue energy drink consumption. [28]

Another case report by Pallangyo P et al. presented a 28-year-old African man with an 8-hour history of severe retrosternal chest pain, shortness of breath, and sweating, which began four hours after consuming five cans of an energy drink containing caffeine, taurine, sugar, and glucuronolactone. He reported a recent pattern of daily energy drink consumption (2–5 cans). Despite being hemodynamically stable on admission and having no major cardiovascular risk factors, his ECG showed significant ST-segment elevation in the anterolateral leads, and elevated troponin and CK-MB levels confirmed a diagnosis of anterolateral STEMI. Echocardiography revealed anterior wall hypokinesia with preserved systolic function. He was treated with aspirin, clopidogrel, and atorvastatin. [27]
These cases highlight the potential for energy drinks to trigger serious cardiac events, even in young adults without traditional cardiovascular risk factors.

Increasing concern has been raised in the literature about the possible cardiotoxic effects of energy drinks. A case was reported of a 21-year-old man who developed severe bilateral heart failure, possibly linked to excessive energy drink consumption. The patient had no notable medical, familial, or social issues, aside from excessive energy drink consumption [16] .

Another article describes the case of a 24-year-old man who consumed 3.4 to 4 liters of energy drinks per day and presented to the emergency department due to worsening shortness of breath. The physical exam showed the presence of orthopnea, crackles in both lungs, and swelling in the lower legs. The ECG indicated a sinus rhythm with a heart rate of 110 bpm and T-wave inversions in leads V4–V6. A chest X-ray revealed a dense shadow in the lower region of the right lung, pointing to a pleural effusion likely related to heart failure. Echocardiography showed a left ventricular ejection fraction of 25%, along with global hypokinesia and enlargement of the left ventricle. Cardiac MRI confirmed both the dilation of the left ventricle and impaired systolic function. The patient underwent diagnostic evaluation to determine the underlying cause, and chronic diseases were ruled out, suggesting that the consumption of energy drinks may lead to serious cardiovascular complications [16].

A case conducte by Di Rocco JR et al. involving a 14-year-old healthy boy highlights the potential arrhythmogenic effects of energy drink consumption in adolescents. The patient presented with palpitations two hours after a race and reported prior intake of highly caffeinated beverages, including Red Bull™, in the days preceding the episode. His ECG revealed narrow-complex atrial fibrillation with intermittent atrial flutter. Following administration of a single dose of digoxin, he converted to normal sinus rhythm. Cardiac evaluation showed no structural abnormalities, and follow-up was unremarkable. This case underscores the possible role of energy drinks in triggering supraventricular arrhythmias even in otherwise healthy pediatric individuals.

A case conducted by Nagajothi N et al, involving a 23-year-old woman with no prior medical history demonstrated that the combined consumption of a caffeinated energy drink (GNC Speed Shot) and a caffeinated soda (Mountain Dew) can provoke supraventricular tachycardia. Shortly after intake, the patient presented with palpitations and chest tightness. Her electrocardiogram revealed a narrow complex tachycardia with a ventricular rate of 219 bpm, which was unresponsive to vagal maneuvers but successfully terminated with intravenous adenosine, indicating atrioventricular nodal reentry tachycardia as the most likely mechanism. This case illustrates how excessive caffeine intake—even in individuals without underlying health conditions—can trigger potentially dangerous arrhythmias, emphasizing the need for public awareness about the risks associated with combining multiple caffeine-containing products. [32]

Nowadays sugar-free energy drink formulations that contain negligible kilocalories and include sport supplements such as beta-alanine and L-citrulline are becoming increasingly popular especially among young athletes. It could be a new threat disguised as a seemingly healthy alternative. [19] The randomized, double-blind, placebo-controlled, crossover trial conducted by Banks NF et al. investigated the acute effects of a non-caloric energy drink compared to a traditional sugar-containing energy drink and a non-caloric placebo on exercise performance and cardiovascular safety.The main findings indicate that acute consumption of traditional, sugar energy drinks increases the respiratory exchange ratio (RER) and decreases maximal fat oxidation (MFO) without affecting the anaerobic threshold, peak oxygen uptake, or performance during a fatiguing isometric exercise bout. In contrast, non-sugar did not

disrupt semi-fasted RER or MFO, but it enhanced impulse during isometric tasks relative to placebo. Neither sugar nor non-sugar drinks had an impact on mood or leg blood flow. Both drinks led to significant increases in resting systolic blood pressure (SBP) and heart rate, likely resulting in elevated diastolic blood pressure (DBP) and rate-pressure product (RPP), but did not affect ventricular repolarization or other indicators of cardiac electrical activity. The long-term effects of habitual consumption of sugar-free versus traditional energy drinks on cardiovascular and metabolic health remain unclear and need futher research. [19]

Furthermore, drinking large amounts of energy drinks—particularly when mixed with alcohol—can potentially trigger atrial fibrillation. This is likely caused by the combined effects of caffeine and other ingredients found in these drinks. Cases have been documented in which young individuals experienced atrial fibrillation (AF) following the consumption of energy drinks [17] . In Walia, R report, a case was described involving a young man who, after consuming several energy drinks, experienced heart palpitations and was subsequently diagnosed with paroxysmal ventricular tachycardia, ventricular bigeminy, and trigeminy [18]. Another case describes a 16-year-old boy with a history of ADHD, asthma, and allergies who developed atrial fibrillation with rapid ventricular response after consuming a combination of Red Bull™ and vodka. He presented with vomiting and intoxication but denied any cardiac or respiratory symptoms. ECG revealed chaotic atrial tachycardia/atrial fibrillation. Despite elevated blood alcohol levels, cardiac enzymes and imaging were unremarkable. After supportive treatment with IV fluids, he spontaneously converted to sinus rhythm within 12 hours and remained asymptomatic at follow-up. This case suggests that the combination of energy drinks, alcohol, and stimulant medications may increase the risk of arrhythmias in adolescents with predisposing factors. Arrhythmias triggered by the excessive consumption of energy drinks pose a risk of sudden cardiac arrest.

Findings from both clinical studies and case reports suggest that energy drinks, whether consumed occasionally or habitually, may have a considerable impact on cardiovascular health. Documented effects range from temporary increases in blood pressure and QTc interval to serious, potentially fatal events, including arrhythmias, myocardial infarction, and heart failure. These outcomes appear especially concerning in individuals with pre-existing heart conditions, as well as in children and adolescents. Ongoing research is essential to determine the long-term cardiovascular risks associated with energy drinks—both sugary and sugar-free versions—and to better understand whether these effects stem from specific ingredients or their combined action.

Conclusion

Available evidence suggest that the consumption of energy drinks may have a harmful impact on the cardiovascular system, particularly when consumed in large quantities or over extended periods. Numerous studies and case reports have documented increases in blood pressure, QTc interval prolongation, arrhythmias, and even acute coronary syndromes in otherwise healthy individuals. While some studies have not demonstrated significant effects, the potential for serious cardiovascular complications remains a concern. Given the popularity of

these beverages among adolescents and young adults, there is a clear need for increased public education regarding their potential risks. Clinicians should consider energy drink consumption as a possible contributing factor in patients presenting with unexplained cardiovascular symptoms. In addition, policy measures such as improved labeling and consumption guidelines may be warranted to reduce the risk of adverse events. Further research is essential to clarify the long-term effects of energy drinks, the specific roles of their various ingredients, and the risks associated with concurrent use of alcohol or intense physical activity. Until such data are available, caution should be exercised, particularly among individuals with known or suspected cardiovascular vulnerabilities.

Disclosure

Author's contribution

Conceptualization: Michalina Piwowar and Katarzyna Blicharz; methodology: Katarzyna Agopsowicz; software: Martyna Biernacka; check: Maria Sitko, Martyna Biernacka and Dominika Stolarczyk; formal analysis: Piotr Zdziebło; investigation: Katarzyna Agopsowicz and Piotr Mojżesz; resources: Igor Biernacki; data curation: Katarzyna Blicharz; writing-rough preparation: Aleksandra Bąk; writing- review and editing: Michalina Piwowar and Piotr Zdziebło ; visualization: Maria Sitko; supervision: Dominika Stolarczyk; project administration: Igor Biernacki;

receiving funding: not applicable

All authors have read and agreed with the published version of the manuscript.

Financing statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgements

Not applicable.

Conflict of interest

The authors deny any conflict of interest.

References

1) Reissig, C. J., Strain, E. C., & Griffiths, R. R. (2009). Caffeinated energy drinks—A growing problem. Drug and Alcohol Dependence, 99(1-3), 1-10. https://doi.org/10.1016/j.drugalcdep.2008.08.002
2) Heckman, M. A., Sherry, K., & de Mejia, E. G. (2010). Energy drinks: An assessment of their market size, consumer demographics, ingredient profile, functionality, and regulations in the United States. Comprehensive Reviews in Food Science and Food Safety, 9(3), 303–317. https://doi.org/10.1111/j.1541-4337.2010.00111.x
3) Seifert, S. M., Schaechter, J. L., Hershorin, E. R., & Lipshultz, S. E. (2011). Health effects of energy drinks on children, adolescents, and young adults. Pediatrics, 127(3), 511–528. https://doi.org/10.1542/peds.2009-3592
4) Yunusa, I., & Ahmad, I. M. (2012). Energy drinks: Composition and health benefits. Bayero Journal of Pure and Applied Sciences, 4(2), 186–191. https://doi.org/10.4314/bajopas.v4i2.38
5) Higgins, J. P., Tuttle, T. D., & Higgins, C. L. (2010). Energy beverages: Content and safety. Mayo Clinic Proceedings, 85(11), 1033–1041. https://doi.org/10.4065/mcp.2010.0381
6) Ângelo, P. C. S., Nunes-Silva, C. G., Brígido, M. M., Azevedo, J. S. N., Assunção, E. N., Sousa, A. R. B., ... & Astolfi-Filho, S. (2008). Guarana (Paullinia cupana var. sorbilis), an anciently consumed stimulant from the Amazon rain forest: The seeded-fruit transcriptome. Plant Cell Reports, 27(1), 117–124. https://doi.org/10.1007/s00299-007-0456-y
7) Ferre, S. (2008). An update on the mechanisms of the psychostimulant effects of caffeine. Journal of Neurochemistry, 105(4), 1067–1079. https://doi.org/10.1111/j.1471-4159.2007.05196.x
8) Clauson, K. A., Shields, K. M., McQueen, C. E., & Persad, N. (2008). Safety issues associated with commercially available energy drinks. Journal of the American Pharmacists Association, 48(3), e55–e63. https://doi.org/10.1331/JAPhA.2008.07055
9) Babu, K. M., Church, R. J., & Lewander, W. (2008). Energy drinks: The new eye-opener for adolescents. Clinical Pediatric Emergency Medicine, 9(1), 35–42. https://doi.org/10.1016/j.cpem.2007.12.002
10) Finnegan, D. (2003). A review of the health effects of stimulant drinks. Nutrition Bulletin, 28(2), 147–155. https://doi.org/10.1046/j.1467-3010.2003.00345.x

11) Basrai, M., Schweinlin, A., Menzel, J., Mielke, H., Weikert, C., Dusemund, B., Putze, K., Watzl, B., Lampen, A., & Bischoff, S. C. (2019). Energy drinks induce acute cardiovascular and metabolic changes pointing to potential risks for young adults: A randomized controlled trial. *The Journal of Nutrition, 149*(3), 441–450. https://doi.org/10.1093/jn/nxy303
12) Svatikova, A., Covassin, N., Somers, K. R., Somers, K. V., Soucek, F., Kara, T., & Bukartyk, J. (2015). A randomized trial of cardiovascular responses to energy drink consumption in healthy adults. *JAMA, 314*(19), 2079–2082. https://doi.org/10.1001/jama.2015.13744
13) Pallangyo, P., Bhalia, S. V., Komba, M., Mkojera, Z. S., Swai, H. J., Mayala, H. A., & Kisenge, P. R. (2023). Acute myocardial infarction following the consumption of energy drink in a 28-year-old male: A case report. *Journal of Investigative Medicine High Impact Case Reports, 11*, 23247096231168811. https://doi.org/10.1177/23247096231168811
14) Ullah, M. W., Lakhani, S., Siddiq, W., Handa, A., Kahlon, Y., & Siddiqui, T. (2018). Energy drinks and myocardial infarction. Cureus, 10(5), e2658. https://doi.org/10.7759/cureus.2658
15) Uyanik, M., Gedikli, O., & Yildirim, U. (n.d.). Energy drink-associated cardiomyopathy after excessive consumption: A case report. OMU Kurupelit Kampusu, Tıp Fakultesi, Samsun, Turkey
16) Fisk, G., Hammond-Haley, M., & D'Silva, A. (2021). Energy drink-induced cardiomyopathy. *BMJ Case Reports, 14*(4), e239370. https://doi.org/10.1136/bcr-2020-239370
17) Mattioli, A. V., Pennella, S., Farinetti, A., & Manenti, A. (2019). Energy drinks and atrial fibrillation in young adults. European Journal of Preventive Cardiology, 26(3), 358-360. https://doi.org/10.1177/2047487319833936
18) Walia, R., & Kaur, S. (2021). Excess of high-caffeinated energy drinks causing ventricular arrhythmias. Journal of Community Hospital Internal Medicine Perspectives, 11(2), 154-156. https://doi.org/10.1080/20009666.2021.1881634
19) Banks NF, Rogers EM, Helwig NJ, Schwager LE, Alpers JP, Schulte SL, Trachta ER, Lockwood CM, Jenkins NDM. Acute effects of commercial energy drink consumption on exercise performance and cardiovascular safety: a randomized, double-blind, placebo-controlled, crossover trial. J Int Soc Sports Nutr. 2024 Dec;21(1):2297988. doi: 10.1080/15502783.2023.2297988. Epub 2024 Jan 10. PMID: 38197606; PMCID: PMC10783828.
20) Shah SA, Szeto AH, Farewell R, Shek A, Fan D, Quach KN, Bhattacharyya M, Elmiari J, Chan W, O'Dell K, Nguyen N, McGaughey TJ, Nasir JM, Kaul S. Impact of High Volume Energy Drink Consumption on Electrocardiographic and Blood Pressure Parameters: A Randomized Trial. J Am Heart Assoc. 2019 Jun 4;8(11):e011318. doi: 10.1161/JAHA.118.011318. Epub 2019 May 29. PMID: 31137991; PMCID: PMC6585360.
21) Oberhoffer FS, Dalla-Pozza R, Jakob A, Haas NA, Mandilaras G, Li P. Energy drinks: effects on pediatric 24-h ambulatory blood pressure monitoring. A randomized trial.

Pediatr Res. 2023 Sep;94(3):1172-1179. doi: 10.1038/s41390-023-02598-y. Epub 2023 Apr 15. PMID: 37061642; PMCID: PMC10444612.
22) Svatikova A, Covassin N, Somers KR, Somers KV, Soucek F, Kara T, Bukartyk J. A Randomized Trial of Cardiovascular Responses to Energy Drink Consumption in Healthy Adults. JAMA. 2015 Nov 17;314(19):2079-82. doi: 10.1001/jama.2015.13744. PMID: 26547226.
23) García A, Romero C, Arroyave C, Giraldo F, Sánchez L, Sánchez J. Acute effects of energy drinks in medical students. Eur J Nutr. 2017 Sep;56(6):2081-2091. doi: 10.1007/s00394-016-1246-5. Epub 2016 Jun 16. PMID: 27312565.
24) Miles-Chan JL, Charrière N, Grasser EK, Montani JP, Dulloo AG. The blood pressure-elevating effect of Red Bull energy drink is mimicked by caffeine but through different hemodynamic pathways. Physiol Rep. 2015 Feb 25;3(2):e12290. doi: 10.14814/phy2.12290. PMID: 25716925; PMCID: PMC4393199.
25) Ragsdale, F. R., T. D. Gronli, N. Batool, N. Haight, A. Mehaffey, E. C. McMahon, et al. 2010. Effect of Red Bull energy drink on cardiovascular and renal function. *Amino Acids* 38: 1193–1200.
26) Solomin D, Borron SW, Watts SH. STEMI Associated with Overuse of Energy Drinks. Case Rep Emerg Med. 2015;2015:537689. doi: 10.1155/2015/537689. Epub 2015 Feb 19. PMID: 25767726; PMCID: PMC4350866.
27) Pallangyo P, Bhalia SV, Komba M, Mkojera ZS, Swai HJ, Mayala HA, Kisenge PR. Acute Myocardial Infarction Following the Consumption of Energy Drink in a 28-Year-Old Male: A Case Report. J Investig Med High Impact Case Rep. 2023 Jan-Dec;11:23247096231168811. doi: 10.1177/23247096231168811. PMID: 37085978; PMCID: PMC10126631.
28) Gharacholou SM, Ijioma N, Banwart E, Munoz FD. ST-Segment Elevation Myocardial Infarction and Normal Coronary Arteries after Consuming Energy Drinks. Case Rep Cardiol. 2017;2017:4061205. doi: 10.1155/2017/4061205. Epub 2017 Jan 19. PMID: 28203465; PMCID: PMC5288504.
29) Wassef B, Kohansieh M, Makaryus AN. Effects of energy drinks on the cardiovascular system. World J Cardiol. 2017 Nov 26;9(11):796-806. doi: 10.4330/wjc.v9.i11.796. PMID: 29225735; PMCID: PMC5714807.
30) Costantino, A.; Maiese, A.; Lazzari, J.; Casula, C.; Turillazzi, E.; Frati, P.; Fineschi, V. The Dark Side of Energy Drinks: A Comprehensive Review of Their Impact on the Human Body. *Nutrients* **2023**, *15*, 3922. https://doi.org/10.3390/nu15183922
31) Costa, B. M., Hayley, A., and Miller, P. (2016). Adolescent energy drink consumption: an Australian perspective. *Appetite* 105, 638–642. doi: 10.1016/j.appet.2016.07.001
32) Nagajothi N, Khraisat A, Velazquez-Cecena JL, Arora R, Raghunathan K, Patel R, Parajuli R. Energy drink-related supraventricular tachycardia. Am J Med. 2008 Apr;121(4):e3-4. doi: 10.1016/j.amjmed.2007.12.003. PMID: 18374674.
33) Di Rocco JR, During A, Morelli PJ, Heyden M, Biancaniello TA. Atrial fibrillation in healthy adolescents after highly caffeinated beverage consumption: two case reports. J Med Case Rep. 2011 Jan 19;5:18. doi: 10.1186/1752-1947-5-18. PMID: 21247417; PMCID: PMC3038953.