

Caffeinated energy drink consumption among adolescents and potential health consequences associated with their use: a significant public health hazard

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Summary. Caffeinated energy drinks (EDs) are increasingly popular among adolescents despite growing evidence of their negative health effects. The consumption of EDs has seen a substantial increase during the past few decades, especially in the Western and Asian countries. EDs contain high levels of caffeine, sugar, and novel ingredients, and are often marketed through youth-oriented media and venues. The known and unknown pharmacology of the constituents of EDs poses a risk of caffeine toxicity and other ill effects when consumed by young people. Caffeine intoxication may result in tachycardia, vomiting, cardiac arrhythmias, seizures, and even death. Other health concerns related to consumption of EDs include obesity and dental enamel erosion resulting from the acidity of EDs. Coingestion of caffeine and ethanol has been associated with increased risk-taking behaviors in adolescent users, impaired driving, and increased use of other illicit substances. Several researchers have demonstrated that consuming alcohol mixed with energy drinks leads to altered subjective states including decreased perceived intoxication, enhanced stimulation, and increased desire to drink/increased drinking compared to consuming alcohol alone. Caffeine's effect on intoxication may be most pronounced when mixers are artificially sweetened, that is, lack sucrose which slows the rate of gastric emptying of alcohol. In conclusion: 1) health care providers should educate youth and their parents about the risks of caffeinated drinks; 2) emergency department clinicians should consider asking patients about ED and traditional caffeine usage and substance use when assessing patient symptoms; 3) policy makers should increase their attention on introducing regulatory policies on television food advertising to which youth are exposed; 4) failure to comply with standards for efficacious product labelling, and absence of broader education regarding guidelines, need to be addressed and 5) further studies must be done to improve our understanding of potential negative consequences of caffeinated energy drinks on health. (www.actabiomedica.it)

Key words: energy drinks, adolescents, caffeine, alcohol use, liver and cardiovascular complications, substance abuse, risk behaviours

Introduction

Energy drinks (EDs) are beverages that contain caffeine and varied other substances, such as guarana,

taurine, ginseng, vitamins, herbal supplements, and sugar (1). They are advertised as increasing energy, improving athletic performance, concentration, reactions, wakefulness, attention, emotions and metabolism, and

reducing physical and mental stress (1). However, these effects are extremely variable, dose dependent and most importantly, have not been well studied in children and adolescents.

EDs differ from sports drinks, which are marketed to accompany physical activity and contain carbohydrates, minerals, electrolytes and flavoring, and are intended to replenish water and electrolytes lost through sweating during exercise.

In the United States, EDs were introduced in 1949 but were not widely used. The first commercially available ED in Thailand, named Krating Daeng, and modelled after a Japanese drink, was introduced in 1976. Red Bull was marketed in Austria in 1987. Subsequently, these became more popular in Europe and Asia in the 1990's. Up to now, they are available in around 140 countries in the world. The popularity of these drinks has increased markedly in recent years. More than 500 new energy drinks were launched worldwide in 2006. EDs are sold in numerous places and are easily accessed by children, adolescents, and young adults (2, 3). Over the past five years, the U.S. retail market for energy and sports drinks expanded in vigorous fashion culminating in sales of \$25 billion in 2016 after rising at an annual rate of 7% over the preceding half decade, according to the market research firm "Packaged Facts" in a new report (4).

Young adults and adolescents are particularly attracted to energy drinks because of effective product marketing, peer influence and a lack of knowledge of the potential harmful effects (2, 3). A great public health concern is related to the trend among young people to consume alcohol-mixed energy drinks (AmEDs), particularly in occasion of social events or dance partying. ED are also consumed by young people often being combined with illicit substances such as amphetamines and marijuana (5, 6).

In a survey of 496 college students, aged 21.5 ± 3.7 years, conducted in the Central Atlantic region of the U.S., 51% reported consuming at least one energy drink in the last month (7). The majority of users consumed energy drinks for insufficient sleep (67%), to increase energy (65%), and to drink with alcohol while partying (54%). Weekly jolt and crash episodes were experienced by 29% of users, 22% reported ever having headaches, and 19% heart palpitations from consuming EDs (5).

Similarly, a study of German adolescents found that 53% tried energy drinks and 26% consumed them regularly (8). Internationally, Thailand was reported to have the highest per capita consumption of energy drinks in 2007, with the United States, Austria, Ireland, New Zealand, Slovenia, and Kuwait rounding out the top seven countries (9).

This article reviews the current literature on EDs with the aim to identify the major ingredients of these beverages and to delineate the potential adverse effects related to their consumption alone or in combination with alcohol in adolescents and young adults.

Constituents of energy drinks

1. Caffeine

The numerous brands of ED share one common factor: all contain caffeine. Caffeine is extracted from the raw fruit of over sixty species of coffee plants (*coffea Arabica*), all part of the methylxanthine family. Caffeine is also extracted from tea, kola nuts, and cocoa. The caffeine content in EDs varies between 50 and 505 mg per can or bottle (10, 11) compared to 80-120 mg and 60 mg in a cup (250 mL) of coffee and tea, respectively (12).

Safe limits of caffeine consumption are still undetermined but data suggest that maximum recommended intake of caffeine per day varies from 2.5 mg/kg/day to 6 mg/kg/day in children, 100 mg/day in adolescents and up to 400 mg/day in adults (13,14). Once ingested, caffeine is rapidly absorbed (30-60 minutes) from the gastrointestinal tract where it is demethylated to form paraxanthine (84%), theobromine (12%), and theophylline (4%). The caffeine half-life, in adults, ranges from approximately 3 to 7 hours with 0.5%-3.5% of its content excreted unchanged in urine and select amounts eliminated via perspiration.

Caffeine is absorbed rapidly and totally in the small intestine in less than 1 h and diffuses rapidly in other tissues (15). Caffeine is soluble in water and lipids, easily crosses the blood-brain barrier, and can be found in all body fluids, including saliva and cerebrospinal fluid (15). The difference in caffeine absorption time is dependent on the physico-chemical formula-

tion properties of the product dose (13,15), and the effects are age dependent and depend on complex genetic and environmental interactions (15). Oral contraceptives tend to double the half-life of caffeine (15).

The effects of caffeine on various organ systems include, in adults, an increase of heart rate, blood pressure, speech rate, motor activity, attentiveness, gastric secretion, diuresis, and temperature (15). Extremely large doses of caffeine can cause acute psychosis and rhabdomyolysis (16). Fatalities from caffeine intoxication although rare, continue to occur (17, 18). A lethal dose of caffeine was considered to be 200 to 400 mg/kg in rats (19, 20).

Manufacturers are not required to list the caffeine content from these ingredients. Thus, the actual caffeine dose in a single serving may exceed that listed (8). In some cans or bottles of EDs the total amount of caffeine can exceed 500 mg (equivalent to 14 cans of common caffeinated soft drinks) and is high enough to result in caffeine toxicity (1).

In 2009, a caffeine related cardiac arrest from energy drinks was reported (19). Electrocardiograms showed that the patient had acute myocardial ischaemia that was probably brought on by caffeine-induced coronary vasospasm. It has been postulated that the pathophysiology of such coronary events involves increased platelet aggregation and reduced endothelial functionality (21).

The treatment of severe caffeine intoxication is generally supportive, and dialysis may be required if the levels of caffeine are extremely high (22).

Beside caffeine, EDs may also contain herbal extracts (guarana, ginseng, yerba mate, ginkgo biloba), glucuronolactone, taurine, inositol, L-carnitine, B group vitamins and carbohydrates.

2. Guarana

Guarana is derived from the seeds of *Paullinia cupana*, a South American plant known for its stimulant properties. Guarana contains large amounts of caffeine (4%–8%), theobromine, theophylline, high concentration of tannins and small amounts of saponins and flavonoids (8). Consumption of guarana increases energy, enhances physical performance, and promotes weight loss. These effects are largely attributed to the high caf-

feine content. Some studies have suggested that the caffeine content of guarana (40 mg per gram of extract) is not always declared in packaging and is additional to the listed caffeine content of energy drinks (8). Hence, the caffeine dose may be higher than that listed on the beverage ingredients list.

Furthermore, it is more slowly absorbed into the gastrointestinal tract and thus has a longer lasting effect than caffeine sourced from coffee beans (21). Guarana is currently thought to have no adverse effects other than potential caffeine toxicity (24).

3. Ginseng (*Panax ginseng*)

Ginseng is a herbal extract famous for its purported stimulant and aphrodisiac properties. It is present in energy drinks below common daily doses, and has not been reported to be toxic. Ginseng, however, has multiple and important drug interactions that may become clinically relevant depending on the amount of ginseng ingested and the dose and frequency of the drugs that might interact with it. Reported symptoms of ginseng toxicity include diarrhea, vaginal bleeding, headache, vertigo, hypertension, rashes, insomnia, irritability, Stevens-Johnson syndrome, and agranulocytosis (25). Some of these symptoms may be related to contaminants, such as phenylbutazone and aminopyrine, used in its processing (8).

4. L-Carnitine

It is an amino acid involved in β -oxidation of fatty acids. It promotes fat metabolism and increased endurance. In high doses, it can cause nausea, vomiting, abdominal pain, and diarrhea. It has been reported to increase seizure frequency in patients with seizure disorder (8).

5. Taurine

Taurine is a normal metabolite in humans that is involved in the modulation of neuronal excitability, membrane stabilization, production of bile salts, and the detoxification of certain xenobiotics. It is estimated that the daily intake of taurine in humans is between 40 and 400 mg. Some energy drinks contain more than

10 times the average person's suggested daily limit of taurine (24). Like caffeine, taurine has physiologic effects on the intracellular calcium concentration in smooth muscles that may cause coronary vasospasm (26).

6. Glucuronolactone

Glucuronolactone is thought to fight fatigue and provide a sense of wellbeing. It is a natural metabolite of glucose and regulates the formation of glycogen. There is very little known about the toxicity of this substance. In some energy drinks, the amount of glucuronolactone is more than 250 times the amount found in other food sources (27).

7. Additional ingredients

Additional ingredients include amino acid, vitamins, herbs, and other supplements purported to boost energy, alertness, and mental performance (28, 29). The quantity of these additional ingredients is highly variable across the spectrum of EDs. L-carnitine, inositol, milk thistle, ginkgo biloba (ginkgo), acai berry, L-theanine and creatine are sometimes added to EDs (19, 24). They have bioactive properties.

Although the effects of caffeine excess have been widely studied, little information is available on potential interactions between these other active ingredients of EDs and caffeine (8, 29).

a. B Vitamins and "energy blend"

Figure 1 depicts the most common ingredients in energy drinks as listed by one group. Many of these ingredients are present in high concentrations, leading to the risk of adverse effects. EDs may contain a mixture of B vitamins and an "energy blend". As listed on one manufacturer's label, the energy blend included taurine, glucuronic acid, malic acid, N-acetyl l-tyrosine, l-phenylalanine, caffeine and citicoline. The B vitamins involved included high amounts of vitamin B12 (cyanocobalamin), B9 (folic acid), B6 (pyridoxine) and vitamin B3 (niacin) and the enzymes included amylase, protease, cellulase, protease, and lactase (30).

Folic acid is required for DNA synthesis, RBC synthesis, and cell growth. According to the National Academy of Sciences, the daily intake of folic acid in adults should not exceed 1000 µg. Very high doses (>15,000 µg/day) can cause stomach problems, sleep problems, skin reactions, and seizures (30).

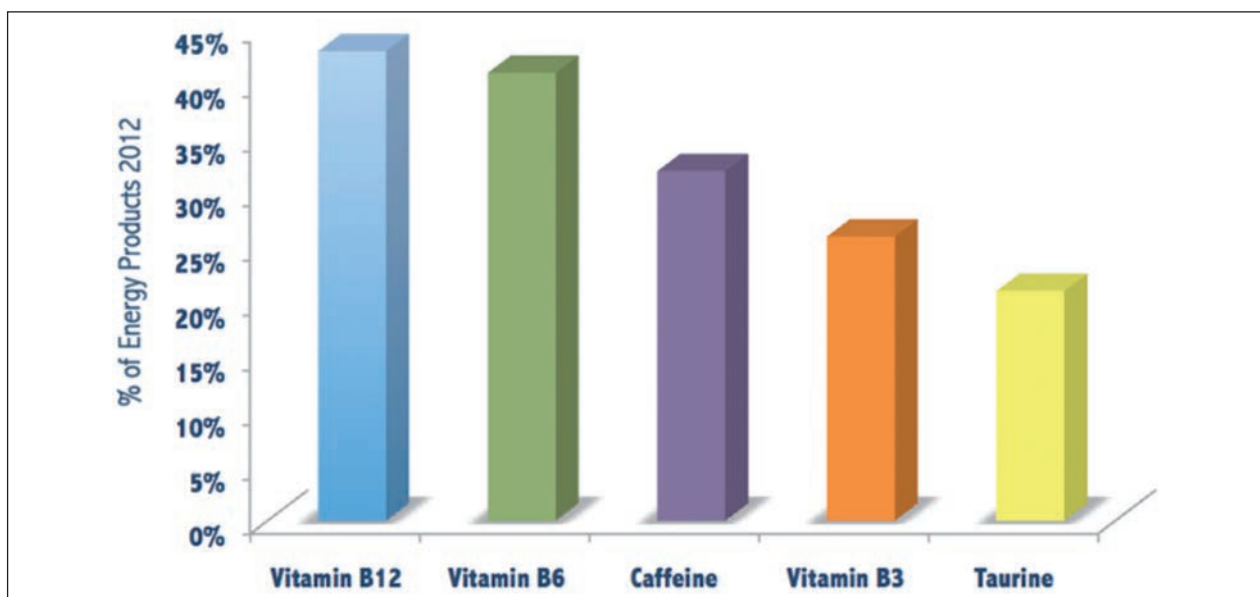


Figure 1. The most common energy drink ingredients (From: <https://www.caffeineinformer.com/energy-drink-ingredients>)

Vitamin B12 is involved in nucleic acid metabolism, the formation of red blood cells (RBCs), and myelin synthesis and repair. It has a very low potential for toxicity even when taken in large doses (30).

Vitamin B6 is important in heme, nucleic acid, lipid, carbohydrate, and amino acid metabolism. Toxicity occurs when megadoses of vitamin B6 (>500 mg/day) are ingested (30). Symptoms of toxicity include peripheral neuropathy with deficits in a stocking-glove distribution, progressive sensory ataxia, and severe impairment of position and vibration senses (30).

Vitamin B3 (Niacin) and its derivatives are vital to cell metabolism. They have been associated with skin flushing and, rarely, to hepatotoxicity (30). However, extended excessive use of this combination of ingredients led to acute hepatitis as described below.

Case reports of hepatotoxicity attributed to vitamin B3 (niacin)

A 22-year-old Caucasian woman presented to the Emergency Department (ED) with epigastric pain, nausea, vomiting, and low-grade fever. She had been drinking 10 cans of an energy drink daily for two weeks prior to presentation. Her aspartate aminotransferase, alanine aminotransferase, and international normalized ratio were markedly elevated. Further radiological studies were non-specific, and she was admitted to hospital with a diagnosis of acute hepatitis. Her viral serology and toxicology screens were negative. The development of acute hepatitis in this patient was most likely due to the excessive ingestion of an energy drink, and the authors speculated that niacin was the culprit ingredient (30).

Harb et al. (31) recently published another case study of a man (50 years old) who consumed about 5 energy drinks a day for a period of three weeks. This caused toxic levels of niacin to build up in his body, leading to non-viral hepatitis.

In conclusion, EDs as well as other herbal/over-the-counter supplements should be considered by clinicians in the workup of patients with acute hepatitis, particularly once other aetiologies have been excluded.

b. Citicoline functions as a neuro-protective agent. It exhibits a very low toxicity profile in humans. **Tyrosine** is involved in the synthesis of neurotransmitters in the brain. **Phenylalanine** is converted to tyrosine in the body and serves the same function as tyrosine. Toxicity symptoms include increased blood pressure, emotional agitation, insomnia, and headaches (30).

c. Malic acid is important in boosting immunity; there are no known reported contraindications or toxicities linked to malic acid (30).

d. Sugar

Another common ingredient in most ED is some type of carbohydrate source (e.g., glucose, sucrose, maltodextrin, ribose, fructose). EDs contain approximately 25-30 grams of carbohydrate per 240 mL serving (range from 0 to 67 g per serving). A typical ED provides carbohydrates at a greater concentration, typically around an 11% -12% solution. Ingesting higher percentages (>10%) of carbohydrate in fluids has been reported to delay gastric emptying and increase gastrointestinal distress (32).

The American College of Sports Medicine (ACSM) recommends ingesting 0.7 g/kg/hr during exercise in a 6-8% solution (i.e., 6-8 grams per 100 ml of fluid) (33). Consequently, athletes who want to use ED as sports drinks may need to dilute the beverage and/or alternate consumption of ED and water during exercise (32).

Furthermore, the high sugar content in caffeinated EDs is similar to other soft drinks and is known to contribute to obesity (34) and alterations of dental enamel (35-37). Most EDs have a pH in the acidic range (pH 3-4). This low pH is associated with enamel demineralization. Citric acid is frequently included in EDs and has been found to be highly erosive, because its demineralizing effect on the enamel continues even after the pH has been neutralized (35-37). Therefore, patients should be instructed on the potential deleterious effects of such beverages when often consumed.

Most energy drinks have sugar-free versions that contain artificial sweeteners. Products including aspartame and saccharin have undergone extensive risk assessment by the United States Food and Drug Ad-

ministration (FDA) and the European Food Safety Authority (EFSA), in relation to a number of potential safety concerns, including carcinogenicity and more recently, effects on body weight gain, glycemic control and effects on the gut microbiome. The majority of the modern day sweeteners (acesulfame K, advantame, aspartame, neotame and sucralose) have been approved in the United States through the food additive process, whereas the most recent sweetener approvals for steviol glycosides and lo han guo have occurred through the Generally Recognized as Safe (GRAS) system, based on scientific procedures (38).

What is not clear is the long-term danger from artificial sweeteners since most studies only considered short-term issues. Results from animal studies in both the agricultural sector and the laboratory indicate that artificial sweeteners may not produce the intended consequences but might contribute to increased risks of obesity or negative health outcomes (39). Furthermore, caffeine's effect on alcohol intoxication may be most pronounced when mixers are artificially sweetened, that is, lack sucrose which slows the rate of gastric emptying of alcohol. As a result, it is critical that the impacts of artificial sweeteners on health and disease continue to be more thoroughly evaluated in humans.

e. Other Vitamins and Minerals

Many EDs contain vitamin C, calcium, and magnesium. Sodium content varies from 85 to 340 mg, and potassium content generally ranges from 60 to 240 mg per serving (240 mL [8 oz]) (33,35).

f. Energy drink preservatives and artificial colors

Besides the active ingredients in energy drinks, there are other chemicals placed in energy drinks to give them a longer shelf-life and a more vibrant color (Table 1).

Alcohol and energy drink use among adolescents

Energy drink use has been positively associated with quantity and frequency of alcohol use, alcohol dependence, marijuana and other drug use, and risk behaviors (40-45).

Table 1. Energy drink preservatives and artificial colors (Source: [https:// www.caffeineinformer.com/energy-drink-ingredients](https://www.caffeineinformer.com/energy-drink-ingredients), modified)

Ingredient	Effect
Benzoic acid	preservative, prevents mold
Blue 1	artificial coloring
Brominated vegetable oil	emulsifier
Calcium disodium EDTA	preservative and sequestrant
Caramel color	food coloring
Citric acid	food coloring
Ester Gum	emulsifier
Gum arabic	food coloring
Monopotassium phosphate	buffering and neutralizing agent
Potassium benzoate	preservative
Potassium sorbate	preservative
Sodium citrate	acidity regulator
Sodium hexametaphosphate	emulsifier
Sorbic acid	preservative
Red 40	artificial coloring
Yellow 5	artificial coloring
Yellow 6	artificial coloring

A survey was conducted during the 2011-2012 school year in northeastern Italy, and involved a sample of 916 students. The usage of energy drinks increased significantly with age, from 17.8 % among sixth graders to 56.2 % among eighth graders. Among the male student population, 16.5 % of those in the eighth grade and 6.21 % of those in the sixth grade drank them at least once a week. The independent variables conferring a higher likelihood of being at least once-a-week energy drink consumers were smoking and alcohol consumption (41).

In another report a sample of 30,588 Italian high school students, aged 15-19 years, was studied. 41.4% and 23.2% of respondents reported drinking EDs and alcohol-mixed energy drinks (AmEDs), respectively, in the last year. Multivariate analysis revealed that consumption of EDs and AmEDs was significantly associated with daily smoking, binge drinking, and use of cannabis and other psychotropic drugs. Among life habits and risky behaviors the following were also positively associated: going out with friends for fun, participating in sports, experiencing physical fights/accidents or injury, engaging in sexual intercourse without protection and being involved in accidents while driving (42).

It has been supposed that caffeine can counteract the sedative effects of alcohol and, therefore, drinkers may not feel the symptoms of alcohol intoxication. Furthermore, the impaired perception of drunkenness can foster longer drinking sessions and an increase in stimulation compared with alcohol-only consumption (43-45).

The link between energy drink use and alcohol dependence might be attributable to the popularity of mixing alcohol with energy drinks or it might be that alcohol-dependent individuals rely on highly caffeinated beverages to manage hangover effects. Therefore, comprehensive educational programs among youths focusing on the potential health effects of EDs, alcohol, and the combination of the two, designed to empower the ability to manage these drinking habits, are strongly advisable. Substantial alcohol intake increases the half-life of caffeine and decreases its clearance (46).

Puberty, caffeine and alcohol abuse

It has been pointed out that subjective mood change and cardiovascular responses to caffeine are dependent on gender and pubertal stage (47, 48). While effects on the former emerge before puberty and sex differences may be strengthened after pubertal development, decreased heart rate and increased blood pressure after caffeine are observed only in late adolescence, after puberty and across the menstrual cycle, with pronounced effects on heart rate during the luteal phase and more pronounced effects on blood pressure during the follicular phase.

Because co-ingestion of EDs and alcohol is frequent, and alcohol may disrupt the timing of pubertal development in females, ingestion of AmEDs in early adolescence may cause pubertal delay (49, 50).

Conclusions

In recent years an increasing number of different energy drinks have been introduced. EDs are now consumed by 30%-50% of adolescents, with 31% of 12-19 year-olds reporting regular use (8), prior to competitions with a view to improve their performance and by a large number of students, especially while studying

for exams. Furthermore, these drinks are also commonly consumed at dance parties, which require sustained energy for prolonged activity into late hours. In this setting, they may also be combined with alcohol (AmEDs) and recreational drugs such as cannabis and other psychotropic drugs.

Consumption of EDs have been associated with multiple medical complications including anxiety, agitation, migraines, gastrointestinal upset, insomnia, arrhythmias, other cardiovascular complications, and in rare cases, even death (8, 15, 50-53). Recent literature has also found an increasing number of problems with behavior modification and cognitive capabilities in adolescents who use EDs (53).

Most cases of toxicity are attributed to caffeine, guarana and taurine. The acute and long-term effects resulting from excessive and chronic consumption of other additives alone and in combination with caffeine are not fully known.

In the US, there was a twofold increase in the number of visits to emergency departments between 2007 (10,068 visits) and 2011 (20,783 visits) that involved EDs, with 12-17 year olds accounting for 11.4% and 7.2% of those visits in 2007 and 2011, respectively (54). Data also indicate that the majority of ED visits were made by patients aged 18-39 years. Out of these ED visits, 56% were secondary to energy drink consumption alone; about 27% of visits were due to energy drinks in combination with pharmaceuticals, 16% in combination with alcohol and, 10% in combination with illicit drugs (16, 54).

Therefore, the FDA imposed a limit of 71 mg of caffeine per 12 fl oz of soda (55, 56). Nevertheless, energy drink manufacturers may circumvent this limit by claiming that their drinks are "natural dietary supplements" (54, 55). As a consequence, in emergency departments clinicians should consider asking patients about ED and traditional caffeine usage and substance use when assessing patient symptoms.

In conclusion, because the potential health risks related to heavy consumption of these products have largely gone unaddressed, it is important for clinicians to be familiar with EDs and the potential health consequences associated with their use. A short revision of the literature on the health outcomes associated with ED consumption is given in Table 2.

Table 2. Health outcomes associated with energy drink (ED) consumption

Authors and health implications	Subjects/Methods	Conclusions
Pommerening MJ et al. <i>J Surg Res.</i> 2015; 199: 635-40. Hypercoagulable state and increased risk of thrombosis.	Thirty-two healthy volunteers aged 18-40 y were given 16 oz of bottled water or a standardized, sugar-free energy drink on two separate occasions, 1wk apart.	EDs are associated with increased platelet activity via arachidonic acid-induced platelet aggregation within 1 h of consumption.
Hajsadeghi S et al. <i>Anatol J Cardiol.</i> 2016;16:94-9. Heart rate and electrocardiographic parameters.	44 healthy participants aged between 15 and 30 years were evaluated.	The consumption of energy EDs could contribute to heart rate decline and ST-T change in healthy young adults.
Avci S et al. <i>Am J Emerg Med.</i> 2013 Nov;31(11):1624.e3-4. Arrhythmia.	A 28-year-old-man admitted to emergency department with ventricular tachycardia	Especially in high doses, caffeine can cause palpitations and supraventricular and ventricular arrhythmia.
Gunja N and Brown JA. <i>Med J Aust.</i> 2012 Jan 16;196(1):46-9. Adverse health effects	Observational study analysing data from calls regarding energy drink exposures recorded in the database of an Australian poisons information centre over 7 years to 2010.	The most common symptoms were palpitations, agitation, tremor and gastrointestinal upset. Twenty-one subjects had signs of serious cardiac or neurological toxicity, including hallucinations, seizures, arrhythmias or cardiac ischaemia. At least 128 subjects required hospitalisation.
Seifert SM et al. <i>Pediatrics.</i> 2011 Mar;127(3):511-28. Adverse health effects	The authors reviewed the effects, adverse consequences, and extent of energy drink consumption among children, adolescents, and young adults	Of the 5448 US caffeine overdoses reported in 2007, 46% occurred in those younger than 19 years.
Petit A et al. <i>Rev Prat.</i> 2012;62:673-8. Adverse health effects	The authors selected scientific reports between 2001 and 2011.	EDs could be responsible for negative consequences on health, particularly among subjects with cardiovascular disease.
Visram S et al. <i>BMJ Open.</i> 2016 Oct 8;6(10):e010380. Adverse health effects	A total of 410 studies were located, with 46 meeting the inclusion criteria. The majority employed a cross-sectional design, involved participants aged 11-18 years, and were conducted in North America or Europe.	A strong, positive association between the use of energy drinks and higher odds of health-damaging behaviours, as well as physical health symptoms such as headaches, stomach aches, hyperactivity and insomnia.
Ali F et al. <i>Postgrad Med.</i> 2015;127:308-22. Adverse health effects	Using PubMed and Google-Scholar, we searched the literature from January 1980 through May 2014 for articles on the adverse health effects of energy drinks. A total of 2097 publications were found.	Adverse health effects of energy drinks. The most common adverse events affect the cardiovascular and neurological systems.

Recognizing the features of caffeine intoxication, withdrawal, and dependence may be especially relevant when treating younger persons who may be more likely to consume EDs. A major challenge for health professionals and researchers is the heterogene-

ity of the numerous ED products available. Regulatory guidelines exist in most developed countries for the safe consumption of caffeine but no international guidelines currently exist that address the safe consumption of EDs. Given all of these factors, it is nec-

essary that more research be conducted on caffeine use among adolescents to understand long-term consequences of caffeine exposure during this critical period of development.

Finally, findings from this review indicate the need for educational intervention to inform adolescents of the consequences of consuming these popular drinks and discuss some of the effects of excessive caffeine, as well as risks associated with EDs mixed with alcohol. AmEDs may act as endocrine disruptors, interfering with pubertal development and reproductive functions.

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