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STIMULANT-CONTAINING ENERGY DRINKS

What You Need to Know

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Apply It!

At the end of this article, you should be able to apply your knowledge to:

- Identify the main active ingredient in energy drinks as caffeine.
- Clearly communicate the potential adverse effects of energy drinks to your clients.
- Pinpoint critical gaps in energy drink regulation, labeling, education, and surveillance.

Key words: Energy Drinks, Caffeine, Adverse Effects, Taurine, Recommendations

INTRODUCTION

Caffeine-containing energy drinks are frequently consumed by up to 80% of athletes, 53% of service members, and 30% of secondary school students, and they are heavily marketed to children and adolescents (1). Advertised for and used to boost performance and stamina, they can contain various other ingredients (vitamins, sugars, herbal extracts, proprietary compounds) as well as high concentrations of caffeine and other stimulants that can cause serious central nervous system adverse effects. Currently, the evidence for safety, efficacy, and performance benefits is limited and conflicting.

Within the U.S. Food and Drug Administration (FDA), energy drinks are classified as either dietary supplements or foods/beverages, both of which provide loopholes regarding their specific contents. Unlike sodas and soft drinks, the caffeine and other stimulants in energy drinks are not regulated and often are not listed on the label (2). The scientific community, media, government, athletic departments, and the general public have expressed safety concerns regarding energy drinks, especially for certain vulnerable populations. Particularly vulnerable populations include those younger than 18 years of age, pregnant or breastfeeding women, individuals taking stimulant or other caffeine-based medications, and those with certain cardiovascular or medical conditions. Despite these concerns, the global energy drink market is forecast to reach 61 billion in U.S. dollars by 2021 (3).

The majority of energy drink-related health concerns seem to be linked to caffeine. However, it is important to note that other stimulants, high levels of sugar, and/or other energy drink substances, such as taurine, may interact and potentiate the impacts of caffeine. In response to these concerns, some groups and legislators have developed policies and educational approaches to limit consumption of energy drinks, particularly in vulnerable populations (4).

ENERGY DRINK INGREDIENTS

Although energy drinks contain a myriad of ingredients, caffeine and other caffeine-like stimulants are the most pharmacologically active. Once ingested, caffeine is rapidly and completely absorbed, generally reaching peak concentrations within 30 to 120 minutes. Pharmacologically, consuming more than 6 mg of caffeine per kilogram seems to saturate hepatic caffeine metabolism. However, there are significant interindividual variations in caffeine metabolism and sensitivity as well as its impacts on alertness and/or performance. When added to energy drinks, caffeine is typically added as a synthetic pure alkaloid (as in pill format) rather than a naturally occurring constituent of plant-based beverages (as in tea or coffee). For example, guarana and yerba mate, which can be contained as part of the energy blend (added vitamin, mineral, and herbal mixtures) of energy drinks, also are natural sources of caffeine, and whose levels and caffeine content often are not part of the package labeling.

Levels of caffeine in energy drinks vary widely but may contain between 71 and 316 mg of caffeine per 8 oz serving, which greatly exceeds the FDA-imposed limit of 71 mg of caffeine per 12 fl oz of soda. As such, energy drinks are considered high sources of caffeine. In addition, energy drinks frequently include significant amounts of carbohydrate (8% to 15%, usually glucose), taurine (an amino acid), niacin, pyridoxine, cyanocobalamin (B12), riboflavin (B2), ginseng extract, glucuronolactone (a glucose metabolite), inositol (B8), guarana (contains caffeine, theobromine, and theophylline), ephedra, Yohimbine, gingko, kola nut, theophylline, vitamins, herbs, and/or L-carnitine (5). The U.S. Poison Control Center reported 552 adverse events between 2000 and 2012, with one death and 24 serious events due to energy drink exposure: 44.7% were in children younger than 6 years of age. Together, the FDA and Poison Control results constitute a signal that regulatory actions may be needed (6).

The health consequences of these additives — alone or in combination — are poorly described. Evidence to substantiate claims that ingredients other than caffeine contribute to performance enhancement is negligible (7). The literature describing adverse events from these additives alone is limited; however, some herbals in energy drinks have been associated with minor to moderately severe adverse effects including seizures, myocardial infarctions, ventricular tachycardia, and gastrointestinal upset. Likewise, the literature describing adverse events from the additives and their interactions with caffeine is even more limited; however, some have raised concern about a possible taurine and caffeine interaction (8).

ENERGY DRINKS AND PERFORMANCE

Caffeine contained in energy drinks has ergogenic potential and may affect both physical and mental performance. Exercise data evaluating both pure caffeine and energy drinks generally show an increase in athletic performance by approximately 2% to 4% (9,10). These benefits extend to muscular, sprint-type, and endurance exercise. The amount of caffeine in energy drinks required to achieve a benefit varies widely and depends on the concentration of caffeine, volume consumed, and the body mass of the consumer. Amounts as little as 1 to 2 mg of caffeine per kilogram body weight have been reported in the literature to be ergogenic, although most performance studies showing benefits were conducted with 3 mg to 6 mg of caffeine per kilogram (9).

The specific mechanism(s) by which caffeine enhances athletic performance has been controversial and difficult to establish because caffeine is distributed to all tissues of the body on ingestion. However, experiments using isolated muscle preparations suggest that caffeine directly potentiates skeletal muscle force, work, and power (11). From a mental perspective, caffeine also may improve auditory and visual vigilance and mitigate fatigue (12). However, it is important to note that the evidence for energy drinks enhancing performance is not as strong as results obtained from studies using the pure alkaloid caffeine or caffeine consumed in pill format. This difference in performance between alkaloid caffeine and energy drinks may be related to variance in the populations studied, amount consumed (often not controlled for body mass), type of exercise, energy drink tested, concentrations of caffeine administered, test circumstances, and the sensitivity of the outcome metrics.

Aside from caffeine, very little evidence suggests that the vitamin, mineral, and herbal constituents of energy drinks elicit any ergogenic benefits. However, the carbohydrate contained in energy drinks may be ergogenic, especially when used during exercise lasting longer than 90 minutes (13).

ADVERSE EFFECTS OF ENERGY DRINK USE

From October 2010 to September 2011, 4,854 calls to U.S. Poison Control Centers regarding energy drink exposures were logged (14). Additives such as alcohol or other stimulants, in combination with the energy drinks, occurred in 3,192 (66%) of the cases. In the remaining 1,480 nonalcoholic energy drink cases (34%), 51% were children younger than 6 years of age, 77% were unintentional, and 61% were males (14). The adverse effects of energy drink use are primarily related to the toxicity of caffeine and other psychoactive stimulants. The characteristic constellation of symptoms and findings associated with caffeine toxicity includes vomiting, tachycardia, hypotension, widened pulse pressure, diaphoresis (excess sweating), mydriasis (pupil dilation), altered mental status, and hypokalemia (low potassium). Other adverse effects can be grouped into cardiac, neurologic, gastrointestinal, renal, and psychiatric adverse effects. The ingredients and the possible mechanisms underlying some of these adverse effects are listed in Table 1.

The cardiac adverse events associated with acute caffeine toxicity and energy drink consumption include tachycardia, hypertension, supraventricular tachycardia, and atrial fibrillation (8). Myocardial infarction (heart attack), coronary artery spasm/thrombosis, vascular dissection, cardiomyopathy (weak/abnormal heart muscle), and sudden cardiac death also have been reported.

TABLE 1: Reported Adverse Effects Associated with Selected Energy Drink Constituents

Ingredient	Proposed Mechanism	Adverse Effects	Reference
Caffeine	Sympathetic stimulation	Increases heart rate, peripheral resistance, blood pressure, and stroke volume. Reduces myocardial blood flow during exercise.	(8,30)
Glucose	Reduces endothelial function Delays gastric emptying and impedes absorption of fluid in the gastrointestinal tract.	Attenuation of blood flow Gastrointestinal upset	(31) (5)
Glucoron-lactone	Reduced endothelial function	Attenuation of blood flow	(31)
Guarana	Sympathetic stimulation – twice the caffeine as coffee; also contains theobromine (a stimulant similar to caffeine).	Increases heart rate, peripheral resistance, blood pressure, and stroke volume.	(32)
Kola nut	Sympathetic stimulation (caffeine and theobromine)	Increases heart rate, peripheral resistance, blood pressure, and stroke volume.	(33)
Taurine	Increase in mean arterial pressure and platelet aggregation.	Increases blood pressure and blood clotting.	(31)
Yohimbine	Sympathetic stimulation	Increases heart rate, hypertension, anxiety, and agitation.	(34)
Yerba mate	Sympathetic stimulation – contains both caffeine and theobromine.	Increases heart rate, peripheral resistance, blood pressure, and stroke volume.	(5,35)

For example, a 28-year-old healthy motocross-racing man experienced a cardiac arrest after consuming 8 cans of energy drinks in 1 day; at the hospital, he was found to have severe coronary artery spasm believed to be secondary to the high caffeine and the taurine content of the energy drink (15). Electrocardiographic findings included QT prolongation and repolarization abnormalities. Cases of sudden cardiac death after energy drink use have been reported; however, direct causation remains unclear in many events (16).

Reported neurologic adverse events after energy drink use include seizures, migraines, cerebral vasoconstriction, stroke, and intracerebral hemorrhage (17). In one of the original papers describing seizures, four adults had generalized seizures in proximity to energy drink use. In three of the four patients, the seizures did not recur on cessation of energy drink use; the fourth patient was lost to follow-up (18). Caffeine can cause vomiting, a common gastrointestinal effect of the drug. Acute renal failure, rhabdomyolysis (skeletal muscle breakdown), and metabolic acidosis also have been described (19). The hypokalemia typically seen in caffeine toxicity is likely due to beta-2 adrenergic receptor agonism and diuresis.

Psychiatric effects, including anxiety, caffeine withdrawal, psychosis, and risky behaviors, have been reported in the setting of energy drink use. Psychosis has been associated with caffeine intake, and there are reports of worsening psychosis in proximity to energy drink use (20). One case involved a young man with no psychiatric history who was hospitalized for psychotic symptoms after excessive consumption of energy drinks (21). In all cases, psychosis improved after discontinuation of caffeine consumption. Increased risk-taking behavior also has been reported in young adults who habitually use energy drinks (22). Physical dependence is a common consequence of repeated caffeine exposure. Symptoms of caffeine withdrawal include malaise, headache, depression, and decreased mental performance.

Concurrent energy drink and alcohol use presents unique concerns. Individuals who consume alcohol with energy drinks report heavier alcohol consumption as well as increased stimulation and alertness. In studies of concurrent alcohol and energy drink use, a consistent pattern of increased alcohol-related harms emerged when compared with other drinkers (23).

SPECIFIC RECOMMENDATIONS

Our recommendations are listed in Table 2 and are summarized here (8,24,25):

1. "Energy drinks should never be consumed by children or adolescents." American Academy of Pediatrics (26). "Energy drinks should not be used for hydration prior to, during, or after physical activity." The National Federation of State High School Associations (5). Warnings should be prominently displayed on the front of products stating vulnerable populations, including those younger than 18 years of age, pregnant or breastfeeding women, caffeine-naïve or sensitive individuals taking stimulant- or caffeine-based medications, or those with certain

TABLE 2: Recommendations Regarding Energy Drinks

Energy drinks should not be:
- Consumed by children or adolescents (26).
- Used for hydration before, during, or after physical activity (5).
- Available in K-12 schools for sale, nor be advertised to children at school.
- Marketed to nor consumed by vulnerable populations.
- Used before, during, or after strenuous activities.
- Consumed with alcohol.
- Consumed close to bedtime.

Health care providers, athletic trainers, personal trainers, coaches, parents, and children should be educated about potential adverse events associated with energy drink use.

cardiovascular or medical conditions, should avoid energy drink use.

2. Regulatory actions are warranted. Health Canada has mandated changes to improve transparency and labels instructing vulnerable individuals to avoid energy drinks (27). The American Beverage Association also favors clearly labeled contents (28). The FDA wants labeling and warnings to ensure the health and safety of susceptible individuals and vulnerable populations (29).
3. Marketing should not appeal to vulnerable populations. Currently, manufacturers of energy drinks advertise on Web sites, social media, and television channels that are highly appealing to both children and adolescents. This targeted marketing to vulnerable populations should not be permitted, and warning labels on the products and Web sites should be required. Efforts should be made to educate consumers regarding the clear and present differences between soda, coffee, sports drinks, and energy drinks.
4. A call for safety standards is necessary. This would then lead to developing a research agenda to prioritize key questions about the acute and chronic effects of energy drink use. At a minimum, standard safety and efficacy studies should be performed and submitted to the FDA by manufacturers. Well-designed and controlled research is required to examine the increasing frequency of adverse events being reported by emergency departments.
5. Education is needed. Health care providers, athletic trainers, personal trainers, coaches, educators, parents, and children should be educated about potential adverse events associated with energy drink use. We also recommend a national registry for surveillance be set up in the United States to specifically track energy drink adverse effects, with mandated reporting requirements by health care providers who believe their patients have experienced adverse events. Continued monitoring of adverse events related to energy drink consumption is needed to fully understand the rate, severity, and nature of reactions to these products across the lifespan.

CONCLUSIONS

Emergency room physicians encounter patients who experience adverse effects associated with energy drink consumption, with death being one possible outcome. Energy drinks are frequently consumed, and there are reports of morbidity and mortality with consumption. Individuals known to be susceptible to adverse events include those of young age, small stature, caffeine-naïve or caffeine-sensitive, pregnant or breastfeeding women, those with certain medical conditions and/or taking certain medications, and those with underlying cardiovascular or other diseases. Consuming multiple energy drinks in one session is a clear risk for adverse events. Of critical importance, children and adolescents seem to be at particularly high risk of complications because of their small body size, caffeine naivety, high caffeine amounts in energy drinks, and hazardous consumption patterns, including frequent and heavy use. Although most healthy adults can consume a single energy drink without any significant negative acute health effects, the long-term effects of chronic consumption have not been well studied. Our ultimate goal is to improve the health and wellness of the general public and inform them of possible dangers associated with energy drink consumption.

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Disclosure: *The authors declare no conflict of interest and do not have any financial disclosures.*

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BRIDGING THE GAP

Caffeine-containing energy drinks should not be consumed for performance or hydration before, during, or after exercise. Coaches, educators, and trainers need to be aware of the potential adverse effects associated with energy drink consumption, especially in children and adolescents. Likewise, open discussions to assess use among athletes and education regarding the potential impacts of energy drinks on sleep, the cardiovascular system, gastric upset, and other adverse effects should be addressed.