Energy Drinks: A Contemporary Issues Paper

John P. Higgins, MD, MBA, M.PHIL, FACC, FACP, FAHA, FACSM, FASNC, FSGC[1]; Kavita Babu, MD, FACEP, FACMT[2]; Patricia A. Deuster, PhD, MPH, FACSM[3]; and Jane Shearer, PhD[4]

Abstract

Since their introduction in 1987, energy drinks have become increasingly popular and the energy drink market has grown at record pace into a multibillion-dollar global industry. Young people, students, office workers, athletes, weekend warriors, and service members frequently consume energy drinks. Both health care providers and consumers must recognize the difference between energy drinks, traditional beverages (*e.g.*, coffee, tea, soft drinks/sodas, juices, or flavored water), and sports drinks. The research about energy drinks safety and efficacy is often contradictory, given the disparate protocols and types of products consumed: this makes it difficult to draw firm conclusions. Also, much of the available literature is industry-sponsored. After reports of adverse events associated with energy drink consumption, concerns including trouble sleeping, anxiety, cardiovascular events, seizures, and even death, have been raised about their safety. This article will focus on energy drinks, their ingredients, side effects associated with their consumption, and suggested recommendations, which call for education, regulatory actions, changes in marketing, and additional research.

Synopsis

The focus of this American College of Sports Medicine (ACSM) Contemporary Issues Paper is on energy drinks and their consumption in relation to physical activity and exercise. The term energy drink refers to high caffeine-containing beverages that often contain a myriad of vitamins, minerals, amino acids, and herbal mixtures. Where applicable, interpretation of the available scientific evidence was made by consensus of the writing group members using the evidence rating system of the National Heart Lung and Blood Institute (Table 1) (1). Data examining the impact of energy drinks on exercise performance were derived from experimental trials and meta-analyses. To assess the risks of energy drinks and their physiological interactions, observational studies and case reports were the primary sources of information. The stated recommendations represent the consensus of the writing panel and incorporate guidance from professional, legislative and educational organizations with positions on energy drinks (*e.g.*, American Academy of Pediatrics, Health Canada, National Federation of State High School Associations).

Introduction

Energy drinks are beverages that typically contain caffeine, taurine, glucuronolactone, vitamins, herbal extracts, proprietary blends, and/or amino acids, and marketed as boosting mental alertness and physical stamina. They are available with or without sugar and may or may not be carbonated, thus the range of products is broad. Importantly, energy drinks are popular, with frequent consumption being reported by athletes, service members, and secondary school students: up to 80% of college athletes reporting use them to potentially enhance their performance (2,3). In addition, energy drinks have been, and continue to be, marketed to children and adolescents (4). The global energy drink market was worth USD 39 billion in 2013, and is forecast to reach 61 billion by 2021 (5).

Despite high market demand, the current evidence for safety, efficacy, and performance benefits is unsystematic and often contradictory, given different protocols and types of products consumed: this makes it difficult to draw firm conclusions (6). Also, much of the available literature is industry-sponsored. One major concern with energy drinks is that they often contain high concentrations of caffeine (7).

According to the U.S. Food and Drug Administration (FDA), 400 $mg \cdot d^{-1}$, or about four or five cups of coffee, is the amount of caffeine "not generally associated with dangerous, negative effects" for healthy adults (8). Anything over that amount could potentially cause serious problems in adults and certainly

[1]McGovern Medical School at The University of Texas Health Science Center at Houston (UTHealth), Houston, TX; [2]Division of Medical Toxicology, Department of Emergency Medicine, UMass Memorial Medical Center, Worcester, MA; [3]Department of Military and Emergency Medicine, Uniformed Services University of the Health Sciences, D Consortium for Health and Military Performance, Bethesda, MD; and [4]Faculty of Kinesiology, Department of Biochemistry and Molecular Biology, Cumming School of Medicine, University of Calgary, Calgary, Alberta, CANADA

Address for correspondence: John P. Higgins MD, MBA, MPHIL, FACC, FACP, FAHA, FACSM, FASNC, FSGC, Division of Cardiology, Lyndon B. Johnson General Hospital, 5656 Kelley St., UT Annex Rm 104, Houston, TX 77026; E-mail: John.P.Higgins@uth.tmc.edu.

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Table 1.
Evidence categories.

Evidence Category	Sources of Evidence	Definition
A	Randomized controlled trials (rich body of data)	Evidence is from endpoints of well-designed RCT (or trials that depart only minimally from randomization) that provide a consistent pattern of findings in the population for which the recommendation is made. Category A therefore requires substantial numbers of studies involving substantial numbers of participants
B	Randomized controlled trials (limited body of data)	Evidence is from endpoints of intervention studies that include only a limited number of RCT, post hoc or subgroup analysis of RCT, or meta-analysis of RCT. In general, Category B pertains when few randomized trials exist, they are small in size, and the trial results are somewhat inconsistent, or the trials were undertaken in a population that differs from the target population of the recommendation.
C	Nonrandomized trials and Observational studies	Evidence is from outcomes of uncontrolled or nonrandomized trials or from observational studies. This level of evidence also includes case reports relating to energy drinks.
D	Panel Consensus Judgment	Expert judgment is based on the panel's synthesis of evidence from experimental research described in the literature and/or derived from the consensus of panel members based on clinical experience or knowledge that does not meet the above-listed criteria. This category is used only in cases where the provision of some guidance was deemed valuable but an adequately compelling clinical literature addressing the subject of the recommendation was deemed insufficient to justify placement in one of the other categories (A through C).

Modified from the National Institutes of Health and National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the Evidence Report. *Obesity Research*. 1998; 6(Suppl 2), 5:51S–209S.

children and adolescents. Importantly, the amount of caffeine in over-the-counter products is limited to a maximum of 200 mg per dose, whereas there is no limit for energy drinks.

Within the FDA, energy drinks are classified as either dietary supplements (require adverse events reporting, but contents not as strictly controlled) or foods/beverages (do not require adverse events reporting, contents strictly controlled), either of which provide manufacturers with loopholes regarding their specific contents, especially the amount of caffeine (9). It is important to recognize the difference between energy drinks and traditional beverages (*e.g.*, coffee, tea, sports drinks, sodas): energy drinks usually have herbal blends, taurine, glucuronolactone, and vitamins in high concentrations (10), whereas traditional beverages do not.

The scientific community, media, governments, athletic departments, and the general public have expressed safety concerns over energy drinks, due to adverse events to include trouble sleeping, anxiety, cardiovascular events, seizures, and even death (2). These safety concerns seem to be especially important in certain vulnerable populations, including those younger than 18 yr, pregnant or breastfeeding women, caffeine naïve or sensitive individuals, individuals taking stimulant or other caffeine-based medications, those with certain cardiovascular or medical conditions, and/or heavy consumption patterns — defined as two or more energy drinks in one session (11).

The majority of energy drink-related health concerns appear to be linked to caffeine, caffeine-like additives, and/or other energy drink substances such as taurine that may interact with caffeine (7). The multiple ingredients, often in combination with heavy consumption patterns, appear to be more problematic than coffee or caffeine alone (12), and particularly in individuals with long QT syndrome (13), an inherited or acquired heart condition.

Unfortunately, marketing for energy drinks primarily targets children, adolescents, and other vulnerable groups with content and experiential based (*e.g.*, high risk sports) advertisements on television channels, internet, and social media sites, and/or as posters, wall murals, digital videos, and other such displays in public transportation venues (14–16). In addition, energy drink companies may provide free samples at youth and adult sporting events. 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 (2). Much of this information forms the basis of the ACSM-endorsed recommendations found at the end of this manuscript.

Energy Drink Ingredients

Caffeine and Caffeine Pharmacology

Caffeine, a methylxanthine, is the most common psychoactive ingredient found in energy drinks. It is rapidly and completely absorbed after ingestion, generally reaching peak concentrations within 30 to 120 min (7). Caffeine is primarily metabolized in the liver by CYP1A2 to a number of physiologically active metabolites, including paraxanthine, theobromine and theophylline (17). Pharmacologically, consuming more than 6 mg of caffeine per kg body mass appears to saturate hepatic caffeine metabolism (17). However, there are significant

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interindividual variations in caffeine metabolism, sensitivity, as well as its impact on alertness and/or performance (17).

Caffeine is usually added as a synthetic alkaloid rather than a naturally-occurring constituent of plant based beverages (as in tea or coffee); however, guarana and yerba mate, which are often present as part of the "energy blend" of energy drinks, are natural sources of caffeine, whose levels are often not part of the package labeling (7). Levels of caffeine in energy drinks vary widely, most contain 32 mg·100 mL^{-1}, but others can contain 30 to 134 mg of caffeine per 100 mL, a concentration greatly exceeds the FDA-imposed limit of 20 mg of caffeine per 100 mL of traditional soda (*e.g.*, Coke, Pepsi). Of note, the caffeine content of small format energy shots (~60 mL) is approximately 6-fold to 12-fold the concentration limit (18). The caffeine content of coffee also can vary widely between 48 mg and 317 mg per serving (19). Although caffeine in coffee also can be harmful, coffee is generally hot, and sipped over a longer period. In addition, the coffee bean contains many beneficial antioxidants, which have been associated with improved metabolic and cardiovascular health (20). Coffee is less frequently consumed by youth, and less likely to be used in a setting of sports and exercise (21). In contrast, energy drinks are usually chilled, highly sweetened, consumed rapidly, and often used in the setting of exercise and sports (18). The caffeine content of selected coffees, teas, sodas, and some popular energy drinks can be found on the caffeine chart at the Center for Science in the Public Interest website: https://cspinet.org/eating-healthy/ingredients-of-concern/caffeine-chart.

There are striking differences in the caffeine doses considered safe by different authorities. One group of authors reported that agitation and tachycardia can occur at doses as low as 50 mg; (2) however, the European Food Safety Authority scientific opinion on the safety of caffeine notes that caffeine doses of less than 200 mg in a 70-kg adult are unlikely to produce toxicity (22). Additionally, the role of rate of consumption and preexisting conditions which may be occult at the time of energy drink exposure (*e.g.*, mitral valve prolapse) in serious energy drink-related adverse events has not been elucidated.

Other Ingredients

Most energy drinks are sweetened with sugar and frequently include taurine (an amino acid), B vitamins (B3, B6, B12) and glucuronolactone (a glucose metabolite) as ingredients. Other minor ingredients can include ginseng extract, guarana (contains caffeine, theobromine, and theophylline), ephedra, yohimbine, gingko, kola nut, theophylline, other vitamins, herbs, and/or L-carnitine (18). The health consequences of these additives — alone or in combination, are poorly described (7). Evidence to substantiate claims that ingredients other than caffeine contribute to performance enhancement is minimal (23); however, a recent meta-analysis found a significant association between taurine dosage and physical performance (24). The literature describing adverse events from these additives alone is limited; however, some herbals in energy drinks have been associated with minor to severe adverse effects including seizures, myocardial infarctions, ventricular tachycardia, and gastrointestinal upset (7,23). Likewise, the literature describing adverse events from the additives and their interactions with caffeine has raised concerns about a possible taurine and caffeine interaction producing endothelial dysfunction (18).

Energy Drink Ingredients and Athlete Testing

Energy drinks have the potential to expose athletes governed by anti-doping rules to inadvertent positive doping tests (25). The primary concern is not caffeine, but rather products that contain proprietary blends, herbals and unrecognizable ingredients that may be banned. The labeling of such dietary supplement ingredients is often unclear and inaccurate (26).

Energy Drinks and Performance

Caffeine contained in energy drinks has ergogenic potential for affecting both physical and mental performance. Exercise data evaluating pure caffeine (*e.g.*, administered in pill or powered format) generally show an increase in athletic performance by approximately 2% to 4% (27–29). These benefits extend to muscular, sprint type, and endurance exercise. The dose required for ergogenic benefit generally ranges from 3 to 6 mg·kg^{-1} body weight, although some studies have reported benefits with lower doses (13,30,31).

The data for energy drinks in relation to performance are less clear, although there appears to be an ergogenic benefit in the range observed for caffeine alone (3.4%) (24,28). Inconsistent and larger variance in energy drink data is likely related to the populations studied, amount consumed, type of exercise, specific energy drink tested, concentration of caffeine administered (not normally administered by body mass), taurine content, test circumstances, and the sensitivity of the outcome metrics (24,28). A recent meta-analysis shows energy drinks have the potential to increase performance in muscle strength and endurance, but not sprinting and power type activities (24). However, the caffeine dosage was not associated with the increases in performance. The authors found a relation between taurine and performance, but given that no analyses of intervention ingredients were conducted, no firm conclusions can be made (24). Although the quality of the studies in the systematic review, as determined by the Physiotherapy Evidence Database (PEDro) scale, ranged from 7 to 10, other important issues for dietary and nutrition intervention studies to ensure transparency and reproducibility are critical (32). These include preparation of dietary ingredient used in the intervention, baseline/background diet, control of diet during intervention, actual analysis of intervention being studied, and analysis of absorption of study ingredients. Because none of these issues were addressed, the quality may be much lower. Lastly, some studies included in the analysis were industry sponsored (not incorporated in the PEDro scale of quality). The impacts of industry sponsorship on study outcomes are well documented (33,34).

Evidence Statement: The acute impacts of caffeine alone on exercise performance are ergogenic, performance may increase by an estimated 2% to 4% depending on the type, intensity, and duration of the exercise performed (ACSM Evidence Category A). Energy drinks also may show benefit, but the evidence is often highly variable, due to poor study design, inconsistent dosing, and industry sponsorship (ACSM Evidence Category B).

Adverse Effects Associated with Energy Drink Consumption

Acute and chronic adverse health effects of energy drinks are still being elucidated, and it is unclear to what extent adverse events occur while individuals are engaged in sport

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or physical activity (18). Based on Australian poison control center data over a 7-yr period, the most commonly reported symptoms after energy drink use were palpitations, agitation, tremor, and gastrointestinal upset (35). Between 2000 and 2012, the U.S. Poison Control Center reported 5103 exposures to energy products and among those 552 adverse events: 1 death, 24 serious, and 527 moderate adverse events. Importantly, 44.7% were children younger than 6 yr (36). According to the FDA's Center for Food Safety and Applied Nutrition Adverse Event Reporting System, between 2004 and 2012, 166 reports were received describing adverse events associated with energy drink consumption, to include 18 deaths (37). Together the FDA and Poison Control results of more than 700 adverse events being reported may constitute a signal that requires regulatory action.

The FDA reports describe a single event and exposure related to acute consumption of an energy drink, but unfortunately do not specify the amount of energy drinks consumed. The FDA's reporting system is estimated to capture only approximately 1% of the true adverse events associated with energy drinks; thus, the number of adverse events and deaths is likely to be much higher (18).

The most common adverse events associated with energy drink consumption are related to their effects on the cardiovascular and neurological systems, followed by gastrointestinal, renal, endocrine, and psychiatric systems (38). It is important to consider that the limited evidence for adverse effects comes from clinical reports, cases studies, and reports on small groups; these levels of evidence are not as strong as randomized studies, however they are all that is available at this time.

The long-term effects of consuming energy drinks are unclear and remain to be documented. Although the epidemiological evidence supporting an association between obesity and type 2 diabetes mellitus and consuming sugar laden beverages is consistent, many other factors in the diet provide excess calories (39). Reducing all sugar sweetened beverage intake (including energy drinks) is likely beneficial in this regard.

Acute Cardiovascular Adverse Effects of Energy Drinks

Endothelial Function

In the majority of well conducted placebo controlled trials, acute exposure to caffeine and other components in energy drinks (typically consumed in less than 5 min) impairs arterial endothelial function (within the next few hours) in healthy young adults at rest (18). Endothelial function is a barometer of vascular health, and abnormal endothelial cell function termed "endothelial dysfunction" acutely is associated with vasoconstriction, poor vascular reactivity, pro-thrombosis, pro-adhesion, pro-inflammation, and growth promotion (18,40). While acute effects of energy drinks on endothelial function suggest a reduction in such function, long-term effects of chronic exposure have not been adequately studied (18).

Hemodynamics

Increased norepinephrine levels of 74% were recently noted in a study involving young healthy volunteers consuming energy drinks (41). Norepinephrine increases heart rate and blood pressure, triggers the release of glucose from energy stores, and increases blood flow to skeletal muscle (41). One to 2 h after consumption of energy drinks, healthy individuals usually have a 6- to 10-mm Hg increase in systolic and 3 to 6 mm Hg increase in diastolic blood pressure, as well as an increase in heart rate of approximately 3 to 7 bpm (18). Such changes may be of concern if an underlying heart condition is present. It is important to remember that excessive caffeine from any source, whether energy drink, tea, coffee, or soda, also can result in increases in blood pressure and heart rate.

Electrocardiographic Abnormalities and Dysrhythmias

A significant increase in corrected QT (QTc) interval in apparently healthy persons 1 to 2 h after consumption of energy drinks of up to 22 to 25 ms has been described (42). Supraventricular arrhythmias, especially atrial fibrillation, can be seen in apparently healthy persons after the consumption of energy drinks (18). Ventricular arrhythmias (ventricular tachycardia and ventricular fibrillation) can be seen in apparently healthy persons, associated with consumption of multiple energy drinks over a short period (18,43). Sudden Cardiac Death has been described in case reports to be triggered by energy drinks, especially in conjunction with exercise (18,43). It is important to note that in many of these cases, confounding variables such as co-ingestions (*e.g.*, drugs, alcohol), genetic predispositions, underlying cardiovascular abnormalities, and strenuous exercise were discovered, so specific causality cannot be attributed to energy drink consumption alone (18). However, some cases of sudden cardiac death have occurred in young healthy individuals, with no predisposing conditions, in association with energy drink consumption (18).

Vascular Pathology

Coronary artery spasm may occur in apparently healthy persons after consumption of multiple (2-8 cans) of energy drinks (18). Coronary artery thrombosis has been associated with consumption of energy drinks in apparently healthy persons, and is likely related to hypercoagulability (increased risk of blood clots), endothelial dysfunction, and elevated norepinephrine levels (18). A single case report described spontaneous coronary artery dissection after energy drink consumption in a healthy child (18). Aortic dissection has been reported to be precipitated after consuming more than the recommended servings of energy drinks (18). ST-segment elevation myocardial infarction in young healthy persons has been associated with excessive consumption of energy drinks (3 to 8 cans), and is likely related to endothelial dysfunction, platelet adhesion, and/or coronary artery vasospasm (18). A single 240- to 250-mL can of an energy drink has been shown to attenuate or result in endothelial dysfunction in healthy young volunteers aged 22 to 34 yr, so consuming just one energy drink may result in adverse effects on endothelial function (44,45). Stress cardiomyopathy or Takasubu cardiomyopathy, an acute heart muscle dysfunction, has been reported in a healthy young 24-yr-old man after consumption of a single energy drink, and the mechanism is likely related to a surge in norepinephrine levels (4,18).

Extra-Cardiac Effects

Neurologic

Several case reports and one National Poison Data System study have noted adverse neurologic effects in association with excessive energy drink consumption. These include

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epileptic seizures, (46–48) reversible cerebral vasoconstriction,(47) and intracerebral hemorrhage (49).

Gastrointestinal

Self-reported symptoms associated with energy drink consumption from emergency room visits indicate about 6% of patients experience gastrointestinal upset with consumption, likely related to the emetic effects of caffeine (50). Two cases have been reported in which patients developed elevated transaminases and jaundice after heavy energy drink consumption with suspected hepatitis; one of these patients had previously undergone orthotropic liver transplantation (49).

Renal

Acute renal failure, rhabdomyolysis, and metabolic acidosis have been described in association with energy drink consumption (49,51).

Endocrine

Obesity is associated with energy drink consumption, secondary to the caloric content, with a usual can of energy beverage containing 54 to 62 g of carbohydrates, usually sucrose, high-fructose corn syrup, and/or glucose (7). Additionally, the endocrine impacts of acute caffeine consumption include hyperinsulinemia and approximately a 30% decline in whole body insulin sensitivity (28,30).

Psychiatric

Acute psychosis also has been reported in the setting of energy drink use (52). When compared with caffeine users, adolescents and young adults who consumed energy drinks were more likely to report mind racing, restlessness or jitteriness, and trouble sleeping (7). Additionally, energy drink users were more likely to report indulging in risk-taking behaviors, including risky driving behaviors (*e.g.*, fast driving and seat belt omission), sexual risk taking, tobacco use, marijuana use, psychedelic drug use, cocaine use, alcohol/binge drinking, other illegal drug use, mixing alcohol and energy drinks, and nonmedical use of prescription stimulants (53,54). Energy drinks may serve as a gateway to other forms of drug dependence (55). Energy drinks are often combined with alcohol, and young adults who mix alcohol with energy drinks consume more alcohol and experience more related harm than other drinkers (56).

Effects in Special Populations

The health concerns associated with energy drink use are amplified in children and adolescents (3,4). Children and adolescents experience adverse effects from energy drinks in greater numbers than adults because of the higher total body concentrations of caffeine relative to body mass, and their relative caffeine naivety (9). In response to concerns that energy drinks negatively affect performance, behavior, and health of schoolchildren and adolescents, the American Academy of Pediatrics and the National Federation of State High School Associations each issued position statements about energy drink use (4,57). In particular they recommended that energy drinks should never be consumed by children or adolescents, or used for hydration before, during, or after physical activity. Additionally, the American Beverage Association has recommended that energy drinks should 1) be marketed as separate from sports drinks, 2) not be sold or marketed in schools, and 3) not be marketed to children (58).

Health Canada also has released a series of measures regarding energy drinks, including caffeine limits, acceptable ingredients, prohibition with premixed alcohol, warning labels for vulnerable populations, and clear labeling of contents (59). Subsequently, the 2015 Dietary Guidelines Advisory Committee, addressed energy drinks and key points included the vulnerability of children and adolescents to the detrimental health consequences of caffeine, as well as the paucity of information on caffeine consumption in this demographic (60).

In case of a severe adverse effect (*e.g.*, palpitations, seizures), emergency care should be sought immediately. Although information can be obtained from regional Poison Control Centers (1-800-222-1222), to facilitate signal detection, consumers and health care providers should report cases of energy drink-associated events via the FDA's Safety Reporting Portal (https://www.safetyreporting.hhs.gov/SRP2).

Evidence Statement: The serious and detrimental impacts of energy drink consumption are well documented in the case report literature *(ACSM Evidence Category C)*. The ACSM writing group concurs that energy drink consumption, especially in vulnerable populations can be potentially hazardous *(ACSM Evidence Category D)*.

ACSM Endorsed Recommendations

The following ACSM recommendations are derived from current legislative and organization guidelines, adverse events reported in the literature and clinical experience and consensus of the collective writing group. All ACSM recommendations are shown in Table 2. Additional substantive recommendations regarding energy drinks can be offered, however implementation of such recommendations requires the efforts of many. The key concepts are detailed here.

- *First, the message that these beverages are not intended for children needs to be re-enforced and widely disseminated.* Warnings should be prominently displayed on the front of products stating vulnerable populations, including those younger than 18 yr, pregnant or breastfeeding women, caffeine naive or sensitive individuals, taking stimulant or caffeine-based medications, or those with certain cardiovascular or medical conditions, should avoid energy drink use (63).
- *Second, regulatory actions are needed.* Many groups have advocated for regulatory limits on the caffeine content of energy drinks, as well as requiring labels to identify the actual amount of caffeine contained per serving (32). Health Canada has already mandated changes to improve transparency and provide labels instructing vulnerable individuals to avoid energy drink use (59). The American Beverage Association also is in favor of clearly labeling contents (58). The Food and Beverage Association in conjunction with the FDA can help ensure the health and safety of susceptible individuals and vulnerable populations, by requiring labeling transparency, clearly labeled warnings, and restriction on sales to those younger than 18 yr until safety and efficacy data are provided by energy drink manufacturers (11).

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Table 2.
ACSM endorsed recommendations regarding energy drinks.

Energy drinks should not be consumed by children or adolescents. We concur with the American Academy of Pediatrics, which has stated that (4): ''energy drinks should never be consumed by children or adolescents;'' and that ''indiscriminant use of energy drinks, especially if more than one serving per day is consumed, may lead to adverse events and harmful side effects.''
Energy drinks should not be used for hydration by children and adolescents, and information about the absence of benefit and potential adverse effects should be provided to those who interact with young persons. We concur with The National Federation of State High School Associations, which has recommended that (57): ''energy drinks should not be used for hydration before, during, or after physical activity.'' and ''information about the absence of benefit and the presence of potential risk associated with energy drinks should be widely shared among all individuals who interact with young athletes.''
Energy drinks should not be available in K-12 schools for sale, nor be advertised to children who attend such schools. We concur with the American Beverage Association who state (58): ''Energy drink manufacturers will not sell or market their energy drink products in K-12 schools.''
Energy drinks should not be marketed to nor consumed by vulnerable populations, including those younger than 18 yr, pregnant or breastfeeding women, caffeine naïve or sensitive individuals, taking stimulant or caffeine-based medications, or those with certain cardiovascular or medical conditions. We concur with Health Canada who (59): Requires statements on the label indicating that the product is "not recommended for children, pregnant/breastfeeding women, individuals sensitive to caffeine", and "do not mix with alcohol'' and requires a statement on the label identifying the product as being a "High Source of Caffeine."
Energy drinks should be avoided before, during, or after strenuous activities, until such time that proper safety and efficacy data are available. Some of the deaths allegedly due to energy drinks have occurred when a person consumed energy drinks before and/or after performing strenuous activities (61).
Energy drinks should not be marketed premixed with alcohol, nor should they be consumed with alcohol. We concur with Health Canada who (59): ''Prohibits the use of Energy Drinks as an ingredient in premixed alcoholic beverages." It should be noted that loopholes which allow "natural caffeine" to be added to alcohol may circumvent this law.
Energy drinks may contain high levels of carbohydrates and calories, which can contribute to obesity. The amount of calories in energy drinks should be carefully monitored by healthy adults who are trying to lose or maintain weight. Likewise, caffeine contained in energy drinks may perpetuate insulin resistance (28).
Energy drinks should not be consumed close to bedtime. Energy drinks or any other substance containing caffeine should be avoided up to 6 h before bedtime to avoid insomnia (62).
Energy drink manufacturers should not promote excessive or rapid consumption of their energy drink, as this pattern has been associated with increased adverse events. We concur with the American Beverage Association who state (58): ''Energy drink manufacturers will not promote excessive or unduly rapid consumption of their energy drink products in any marketing or advertising materials.''
Education about energy drinks and their potential adverse events should be encouraged, especially in schools and universities. Energy drink education, specifically their contents and possible adverse events, should be added to and discussed as a priority in school-based curriculums related to health and nutrition.
Health care providers, athletic trainers, sports medicine physicians, personal trainers, should educate their patients or clients about energy drink use and potential adverse events. This will help inform them about the potential for energy drink adverse events so they can make informed choices about whether to consume them or not.

- *Third, marketing should not appeal to vulnerable populations.* Currently, manufacturers of energy drinks advertise on websites, social media, and television channels that are highly appealing to both children and adolescents (15). Marketing should not be permitted to themes, sporting, and other events involving children and adolescents. Investment in awareness and educational resources highlighting the potential adverse effects and safe use of energy drinks is required in these populations. Significant efforts should be made to educate consumers regarding the clear and present differences between soda, coffee, sports drinks, and energy drinks. Energy drink education also should be a priority in school-based curricula related to nutrition, health, and wellness.
- *Fourth, more data are needed.* A research agenda must be developed 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 (32,64). It appears that most healthy adults can consume a single energy drink without adverse effects (7). However, some healthy adults may have a genetic predisposition or sensitivity to their contents that may lead to adverse effects after consuming only one (18).
- *Fifth, education is needed.* Health care providers must talk to their patients, both young and old, about energy drink use, and report adverse events to watchdog agencies, like the Poison Control Centers, Consumer Product Safety Commission, and the FDA. We also recommend a national registry be set up in the United States to specifically track energy drink side effects, with mandated reporting requirements by health care

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providers who believe their patient has suffered an adverse event. 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

Energy drinks are frequently consumed and there are reports of morbidity and mortality associated with their consumption. In particular, individuals known to be more 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, consuming multiple energy drinks in one session, and those with underlying cardiovascular or other diseases. Of critical importance, children and adolescents appear to be at particularly high risk of complications from energy drinks due to their small body size, being relatively caffeine naive, and potentially heavy and frequent consumption patterns, as well as the amounts of caffeine. Although most healthy adults can consume an energy drink without any significant, negative, acute health effects, the long-term effects of chronic consumption have not been well studied. We have summarized the available information regarding energy drinks and their adverse events, and provided recommendations that we hope will help improve the health and wellness of the general public, and inform them of possible dangers associated with energy drink consumption.

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