

Evidence and knowledge gaps for the association between energy drink use and high-risk behaviors among adolescents and young adults

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Sales of energy drinks have increased rapidly since their introduction to the marketplace in the 1990s. Despite the health concerns raised about these beverages, which are often highly caffeinated, surprisingly little data are available to estimate the prevalence of their use. This review presents the results of secondary data analyses of a nationally representative data set of schoolchildren in the United States and reviews the available research on the association between energy drink use and risk-taking behaviors. Approximately one-third of the students surveyed were recent users of energy drinks, with substantial variation by age, sex, and race/ethnicity. Among the health and safety concerns related to energy drinks and their consumption is the possible potentiation of risk-taking behaviors. The review of available research reveals that, although there does appear to be a strong and consistent positive association between the use of energy drinks and risk-taking behavior, all but one of the available studies used cross-sectional designs, thereby limiting the ability to make inferences about the temporal nature of the association. Thus, more research is needed to understand the nature of this association and how energy drinks, particularly those containing caffeine, might impact adolescent health and safety, especially given the high prevalence of their use among youth.

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INTRODUCTION

Although no formal definition has been proposed, beverages labeled and marketed as energy drinks comprise a heterogeneous beverage category, with most of these drinks containing caffeine and a variety of other ingredients, including guarana, taurine, and B vitamins.^{1,2} Several types of energy drinks are additionally carbonated and contain sugar,^{3,4} although sugar-free variations are available.⁵ Public health concerns have been raised, primarily because of the high levels of caffeine these beverages typically contain, both in amount and in concentration. The amount of caffeine varies considerably, ranging from 50 to 500 mg per container,⁶ with some containers containing more than a single serving.⁷ Energy shots come in smaller-sized containers, typically less than 3 oz. The caf-

feine concentration in energy shots differs by product, with some products containing in excess of 100 mg per fluid ounce.⁶ Currently, no maximal limit on caffeine is imposed by the US Food and Drug Administration for either caffeine-containing energy drinks or energy shots. In contrast, the maximal limit on caffeine in a cola-type beverage is 71 mg per 12 oz serving.⁸

Energy drinks were first introduced to the US marketplace in the late 1990s, and since then, there has been rapid growth in both the number of different types of products available and the varieties within a particular brand.⁶ Industry data indicate that energy drinks and energy shots constitute one of the fastest growing segments of the beverage market, with sales in the United States expected to increase from \$12.5 billion in 2012 to \$21.5 billion in 2017.⁹

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Along with the rise in popularity of energy drinks has been an increase in reports of emergency department visits related to their use. Namely, from 2007 to 2011, there was an estimated twofold increase in the number of individuals presenting to emergency departments after consuming an energy drink (from 10,068 in 2007 to 20,783 in 2011).¹⁰ A majority of these individuals were between 18 and 39 years of age, with 42% using another substance (such as prescription medications) in addition to the energy drink. In 2011, 1,499 adolescents between the ages of 12 and 17 years were admitted to the emergency department following consumption of an energy drink either alone or in combination with another substance. Multiple cases in which consumption of such beverages resulted in hospitalization have been reported voluntarily to the US Food and Drug Administration's Center for Food Safety and Applied Nutrition Adverse Event Reporting System^{11,12}; however, data on hospitalizations resulting from the use of energy drinks are not systematically collected. Recent concerns about possible cardiovascular effects from high levels of caffeine in energy drinks have been raised in the scientific literature.^{7,13-16} More generally, the American Academy of Pediatrics has raised safety concerns about the inclusion of energy drinks in the diets of children,¹⁷ and the American Medical Association issued a resolution to ban the marketing of these beverages to individuals under the age of 18 years.¹⁸

Data to describe consumption patterns among the US population are scarce. Federally funded US national epidemiologic surveys that track annual trends in health behaviors and nutritional habits among adults and children have included very few questions about the consumption of energy drinks. In 2010, the National Health Interview Survey included a supplement containing the following question on the topic: "During the past month, how often did you drink sports and energy drinks, such as Gatorade, Red Bull, and Vitamin Water?"¹⁹ To our knowledge, there have been no published reports of these data. The National Health and Nutrition Examination Survey accepts entries of energy drinks as part of a 24-h dietary recall on beverages, and provides example cards of energy beverages but it does not specifically inquire about their consumption.²⁰

One of the most widely used surveys to measure the health-risk behaviors of American schoolchildren is the NIH-funded Monitoring the Future (MTF) Survey, which began including questions about energy drinks in 2010. Estimates of consumption of alcohol containing caffeine became available in the MTF reports in 2011 and indicated that 10.9%, 19.7%, and 26.4% of eighth, tenth, and twelfth graders, respectively, consumed caffeinated alcoholic beverages during the past year.²¹ For college students and young adults between the ages

of 19 and 28 years, these estimates were even higher (33.8% and 36.7%, respectively). Although the data are publicly available, the annual MTF reports have not included consumption estimates for energy drinks and energy shots without alcohol. Nevertheless, an analysis of the MTF data on energy drinks and energy shots, conducted by Terry-McElrath et al.,²² found an association between the frequency of their consumption and substance use; however, that study analyzed the use of energy drinks and energy shots as one variable, rather than analyzing use of the products separately. Additionally, the study did not describe subgroup variation of energy drink or energy shot use by race or grade level and did not report data on the quantity of energy drinks consumed.

It is important to understand the extent to which energy drinks are becoming a part of the adolescent and young-adult diet. The nutritional requirements during adolescence, defined as the period between the ages of 13 and 18 years, is marked by complex hormonal changes that result in pubertal development and growth. The rapid physical growth that occurs during this period requires the increased intake of calories, protein, vitamins, and minerals.²³ Future eating patterns are often established during adolescence, making this a critical period with lifelong nutritional implications.²⁴

No research could be located that focused specifically on the potential effects of caffeine consumption on physical growth and development during childhood and adolescence. However, the effects of caffeine use on disrupted sleep patterns are well recognized.²⁵ Interestingly, daytime sleepiness related to caffeine and other substance use has been shown to be related to poor academic performance among a large sample of adolescents.²⁶ A laboratory study of caffeine use during a critical developmental period has shown a relationship between caffeine administration and decreases in sleep quality and brain maturation.²⁷

In addition to the attention paid to the possible cardiovascular effects of consuming high levels of caffeine,^{7,13-16} other research studies have pointed to an association between consumption of energy drinks and different types of risk-taking behavior among adolescents and young adults. Adolescence is a peak developmental period for risk-taking, which many believe is normative and biologically driven.²⁸ New research in the field of developmental neuroscience has shed light on the complex structural and functional changes that take place in the brain from adolescence through the early 20s.²⁹⁻³⁵ These changes might explain why adolescents are more likely than older individuals to take risks without regard for possible consequences and why there might be an inherent reliance on peers when making decisions.

Because of the pharmacologic stimulating properties of caffeine, it is possible that consumption of caffeine-containing energy drinks might potentiate the risk-taking behavior that is normative to adolescent development. At least two non-mutually exclusive mechanisms have been suggested to explain the relationship between energy drinks and substance use. First, from a biological perspective, through its interaction with dopamine, early caffeine use could potentially prime neural reward circuitry such that the individual experiences a more positive response to other drugs.^{36,37} Supporting this hypothesis is evidence suggesting cross-sensitization between caffeine and nicotine.³⁸ Second, consumers of energy drinks might be more likely to use other drugs because of an underlying general propensity for risk-taking.

The present review reports prevalence estimates of energy drink and energy shot use by grade, gender, and race/ethnicity from secondary data analyses of the MTF data set. These findings are complemented with a summary of results from studies utilizing college student and adult samples. Secondly, the review summarizes research to date on the link between use of energy drinks and various forms of risk-taking behavior.

USE OF ENERGY DRINKS DURING ADOLESCENCE

Data from MTF surveys are available for public use via the National Addiction and HIV Data Archive Program.³⁹ To estimate the prevalence of energy drink consumption among adolescents in the United States, data were analyzed from the 2010 and 2011 surveys, which represented the most recent data available at the time the analyses were performed. These secondary data analyses were approved by the University of Maryland Institutional Review Board. MTF is a cross-sectional paper-and-pencil survey administered annually to eighth, tenth, and twelfth graders attending more than 100 public and private schools across the 48 contiguous states.⁴⁰ Multistage random sampling occurs first at the level of geographic areas, or “primary sampling units”; next, at the school level within each selected geographic area; and, finally, at the class level within each selected school. Surveys are then self-administered to all students in selected classrooms (or the entire school, for smaller schools). Due to the large number of topics assessed, several alternative forms of the MTF questionnaire are developed each year (i.e., six for twelfth graders; four for eighth and tenth graders), with each form containing only a subset of all possible questionnaire items. Forms are distributed randomly, and the resulting subsamples show no significant differences.

Response rates for the 2011 survey ranged from 83% for twelfth graders to 91% for eighth graders.⁴⁰ Data were

downloaded from the National Addiction and HIV Data Archive Program and analyzed using SPSS statistical software⁴¹ to estimate the prevalence of energy drink use and examine variations in prevalence estimates by grade, gender, and race/ethnicity. Standard weighting procedures were used to adjust for differences in selection probabilities at each level of the sampling design (i.e., students, schools, and geographic areas) by assigning a sampling weight, provided in the dataset, for each respondent.⁴² Valid data from 2011 on the use of energy drinks and/or energy shots were available for 5,207 eighth graders, 4,965 tenth graders, and 2,209 twelfth graders (weighted sample sizes). Analyses were replicated using data collected in 2010 from separate samples of comparable size (5,036 eighth graders, 5,089 tenth graders, and 2,142 twelfth graders); however, for ease of presentation, comparisons across demographic subgroups are presented herein for 2011 data only.

The questionnaire provided participants with the following background information: “Energy drinks’ are nonalcoholic beverages that usually contain high amounts of caffeine, including such drinks as Red Bull, Full Throttle, Monster, and Rockstar. They are usually sold in 8- or 16-ounce cans or bottles” and “Energy drinks are also sold as small ‘shots’ that usually contain just 2 or 3 ounces.” The questionnaire did not differentiate between sugar-containing and sugar-free energy drinks, nor did it differentiate between caffeine-containing and non-caffeinated energy drinks. Ordinal responses to the original survey question, “About how many (if any) energy drinks do you drink per day on average?” were recorded into a three-level categorical variable representing daily use (“One,” “Two,” “Three,” “Four,” “Five or six,” and “Seven or more” per day), less than daily use (“Less than one” per day), and non-use (“None”). No timeframe was specified in the original question; therefore, current use was operationalized as encompassing both daily use and less than daily use. Similar procedures were used for energy shots.

Figure 1A displays the 2011 prevalence estimates of energy drink use by gender and race/ethnicity for eighth, tenth, and twelfth graders. Overall, 35% of eighth graders and 29% of both tenth and twelfth graders indicated they used energy drinks. One striking observation is that eighth graders were more likely to consume energy drinks compared with tenth and twelfth graders. For every grade, males were more likely than females to use energy drinks. Black individuals had the lowest prevalence of energy drinks use regardless of grade. The highest prevalence was observed among Hispanic eighth graders (43%), and the lowest among black twelfth graders (19%).

Figure 1B presents similar data related to energy shot consumption. Overall, the consumption of energy shots

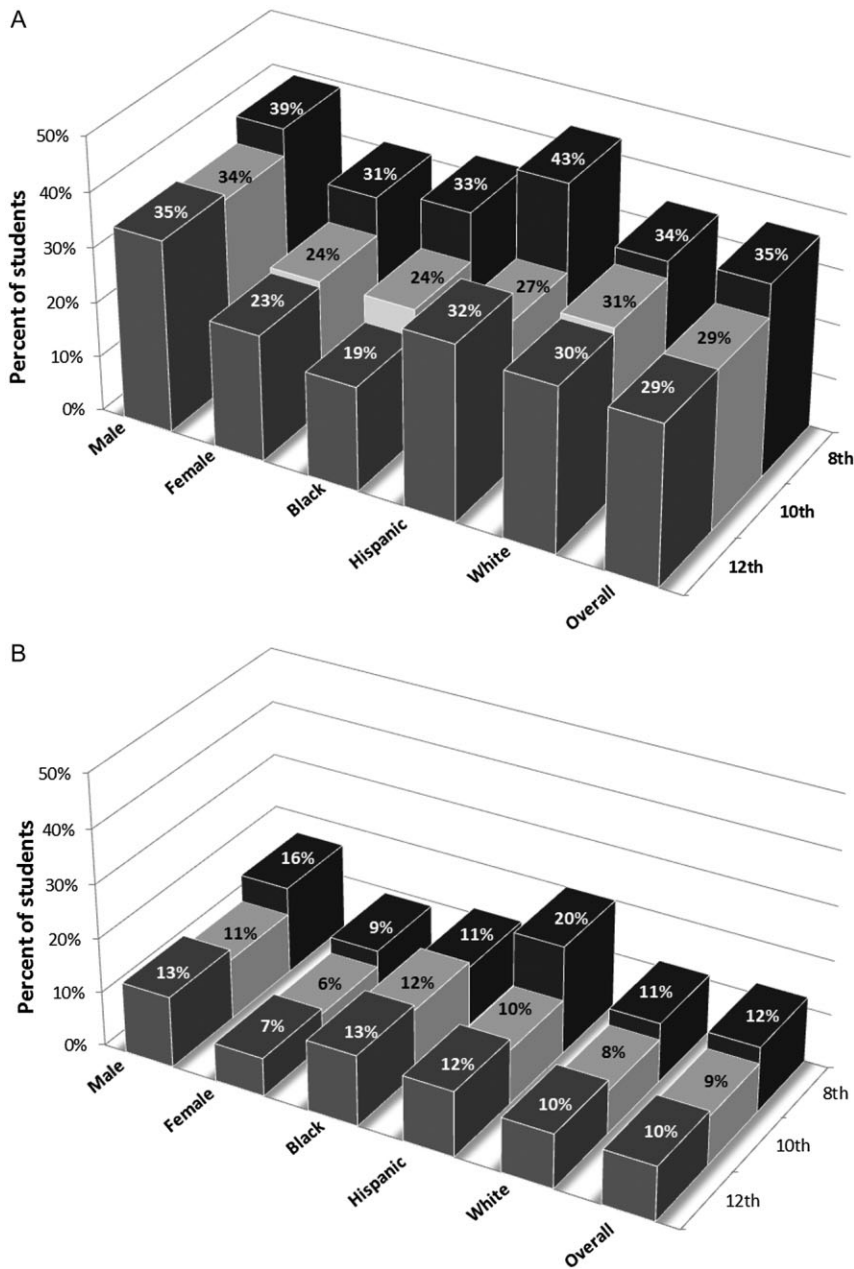


Figure 1 Prevalence of recent energy drink (A) and energy shot (B) use, by sex, race, and school grade.

was less prevalent than for energy drinks, with 12%, 9%, and 10% of eighth, tenth, and twelfth graders, respectively, using energy shots. While gender differences were similar to what was observed for energy drinks, racial/ethnic variations were less apparent. However, Hispanic eighth graders stood out as having a particularly high prevalence (20%) relative to all other subgroups.

Because questions on energy drinks and energy shots were asked separately, it was possible to examine the proportions of students consuming both types of products. As shown in the lowest layer of bars in Figure 2, between

8% and 12% of students consumed both energy drinks and energy shots. Interestingly, almost all of the energy shot users also consumed energy drinks. Between 20% and 24% consumed energy drinks, but not energy shots, as shown in the highest layer of bars. It is also noteworthy that there is considerable consistency in the results from 2010 and 2011.

Table 1 shows data on the daily use of energy drinks and energy shots. Eighth graders showed the highest prevalence of daily use for both energy drinks (18%) and energy shots (7%). Consistent with results from Figures 1A and 1B, Hispanic eighth graders stood out

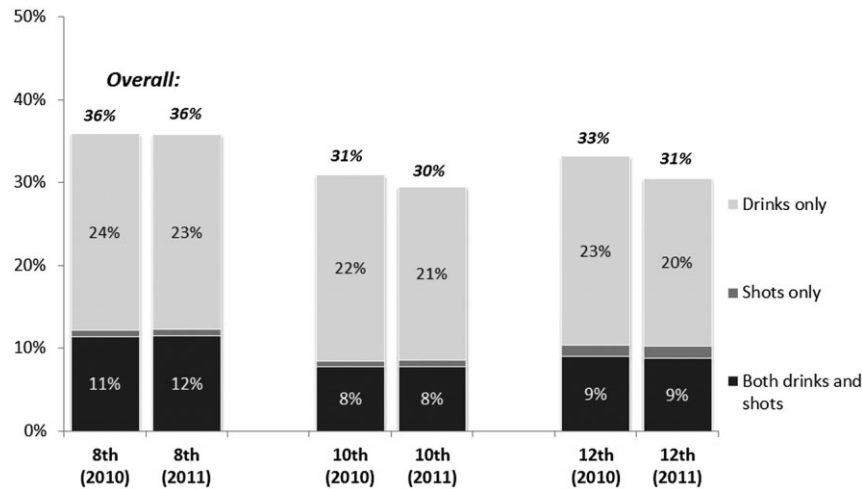


Figure 2 Prevalence of recent use of energy drinks and/or shots, by school grade and year.

again as the subgroup with the highest prevalence of daily use (22% for energy drinks and 11% for energy shots).

Among individuals who consumed these products, most drank only one or less than one per day (see Table 2). Although individuals who drank two or more per day were in the minority, their proportion decreased with age, similar to the trends observed in overall prevalence of use and daily use. For instance, 24% of eighth graders consuming energy drinks were drinking two or more per day, compared with 16% and 13% of their counterparts in the tenth and twelfth grade, respectively. This trend was evident in all six of the subgroups

examined, but was perhaps most pronounced among Hispanics, with nearly a threefold difference in two-a-day use between eighth and twelfth graders (30% versus 11% drinking two or more energy drinks per day). On the other hand, two-a-day use was most prevalent among black eighth graders (33%). The age-related decrease in quantity consumed was less consistent for energy shot users. In at least two subgroups – namely, females and blacks – the proportion of energy shot users drinking two or more shots per day changed very little with age.

Table 1 Prevalence of daily use of energy drinks and energy shots by school grade, sex, and race.

Group	Energy drinks		Energy shots	
	2010	2011	2010	2011
Eighth graders	18.5	17.7	6.4	6.9
Males	22.5	20.1	7.6	8.5
Females	15.1	15.2	5.1	5.3
White	17.2	15.7	4.9	5.5
Black	17.3	21.1	6.1	7.7
Hispanic	22.4	22.3	9.5	11.0
Tenth graders	13.6	11.5	4.2	4.5
Males	16.9	14.1	5.6	5.7
Females	10.0	9.1	2.8	3.4
White	12.5	11.0	3.3	3.7
Black	14.6	12.8	7.4	7.6
Hispanic	16.1	12.5	4.8	5.5
Twelfth graders	12.2	9.6	4.3	4.2
Males	14.8	11.6	6.0	4.7
Females	8.7	7.7	2.2	3.6
White	12.1	8.6	2.8	3.7
Black	9.6	7.8	5.6	7.5
Hispanic	10.2	13.9	6.9	4.7

Data from the 2010 and 2011 Monitoring the Future surveys.⁴²

USE OF ENERGY DRINKS AMONG COLLEGE STUDENTS

The prevalence of energy drink use among college students is presented in Table 3. As the table illustrates, use of these beverages varied substantially among the samples studied, primarily because of the different timeframes used to assess consumption. Both Arria et al.⁴⁴ and Miller⁴⁵ reported that 10% of college students in their samples were “weekly” consumers. Other researchers reported higher estimates for weekly consumption.⁴⁸ In one study of energy drink consumption patterns, Malinauskas et al.⁵ found that 51% of college students consumed more than one such beverage each month in an average month during the past semester. Across the various studies, even with the differences in methodology, use of energy drinks appears to be even more common among college students than younger adolescents.

RELATIONSHIP BETWEEN ENERGY DRINK USE AND RISK-TAKING BEHAVIORS AMONG COLLEGE STUDENTS

Several observational studies and one experimental study have examined the association between energy drink use

Table 2 Number of energy drinks and energy shots consumed per day, among self-reported users, by sex, race, and school grade.

No. of energy beverages consumed/day	Male (%)		Female (%)		Black (%)		White (%)		Hispanic (%)		Total (%)						
	8 th	10 th	8 th	10 th	8 th	10 th	8 th	10 th	8 th	10 th	8 th	10 th					
Energy drinks																	
<1	48.9	58.7	66.8	61.3	67.2	35.9	47.4	57.8	53.8	64.1	71.3	47.6	53.6	56.5	50.1	60.6	67.5
1	26.3	24.0	19.9	22.7	17.6	31.2	26.2	21.1	25.8	22.0	16.9	22.8	26.6	32.1	25.8	23.2	19.9
2 or more	24.8	17.3	13.3	16.0	15.2	33.0	26.4	21.2	20.4	13.9	11.7	29.5	19.8	11.4	24.1	16.2	12.5
Energy shots																	
<1	45.4	49.1	64.9	44.5	50.3	33.1	34.5	42.8	47.5	53.3	63.2	44.8	43.7	60.7	44.8	48.2	59.3
1	21.5	21.6	18.3	25.1	18.4	20.1	24.3	15.8	26.1	26.6	20.4	20.2	8.5	17.5	23.5	22.7	19.1
2 or more	33.0	29.3	16.8	30.4	31.3	46.8	41.2	41.4	26.4	20.0	16.4	35.0	47.8	21.8	31.6	29.0	21.6

Data from the 2011 Monitoring the Future survey.⁴²

and various types of risk-taking behaviors (see Table 3). All of the studies were conducted among college students and young adults, except for one study of 18–45-year-old musicians. All but one of the studies gathered data using cross-sectional survey designs, whereby questions about energy drink consumption were asked along with questions about risk-taking behaviors. The results of these studies are consistent and clearly show that users of energy drinks are more likely to engage in risk-taking behavior.

Many forms of risk-taking behavior have been investigated, including use of marijuana, tobacco, and other forms of drugs, risky sexual behavior, and seat belt omission. Consumption of energy drinks, regardless of whether they were mixed with alcohol at the time of consumption, has been associated with alcohol-related outcomes. In a study of 298 college students, Skewes et al.⁴⁸ found a positive association between the typical number of energy drinks consumed per week and measures of alcohol dependence, current symptoms of alcohol dependence, and alcohol-related problems when controlling for age, gender, and frequency of binge drinking. Specifically, consumption of energy drinks was positively associated with scores on the Alcohol Use Disorders Identification Test (a screening tool used to identify hazardous drinking), the Young Adult Alcohol Consequences Questionnaire (a measure of alcohol-related problems), and the Short Alcohol Dependence Data questionnaire (a measure of current alcohol dependence symptoms). Typical frequency of energy drink consumption was also associated with two types of alcohol use motives: enhancement motives (i.e., drinking for enjoyment or for fun) and coping motives (i.e., drinking to forget one's problems).

Arria et al.⁴⁴ found a positive relationship between the frequency of energy drink use and risk for alcohol dependence among college students, even after statistical adjustment for the level of alcohol consumption (i.e., typical quantity) and a wide range of background variables and other known risk factors for alcohol dependence, including sensation-seeking, conduct problems before the age of 18 years, the age of first alcohol intoxication, depressive symptoms, and parental history of alcohol problems. Demographic variables also included in the model were sex, race/ethnicity, socioeconomic status, and involvement in a fraternity or sorority. Also unique to this study was that use of other caffeinated products was measured and used as a covariate in the analyses. The breadth of variables included in this model was important because it points to the possibility that energy drink use and alcohol dependence might be inter-related in a meaningful way, rather than merely co-occurring due to shared risk factors, such as a general propensity to drink more alcohol.

Table 3 Summary of studies investigating the relationship between energy drink use and risk behaviors.

Reference	Sample	Study design	Prevalence of energy drink use	Risk behaviors studied	Results
Arria et al. (2010) ⁴³	1,060 college students	Prospective	Typical use: 23% (year 2); 36.5% (year 3)	Incident use of eight drugs	Use associated with incident nonmedical prescription drug use and frequency of tobacco smoking ^a
Arria et al. (2011) ⁴⁴	975 college students	Cross-sectional	Past-year use: 51% less than weekly; 10% weekly use	Alcohol use and related problems, alcohol dependence	Use associated with alcohol dependence ^a
Miller (2008) ⁴⁵	602 college students	Cross-sectional	Past-month use: 38%	Marijuana, tobacco, alcohol, and prescription drug use, sexual risk-taking, seat belt omission	Use associated with risk-taking; race/ethnicity difference existed
Miller et al. (2011) ⁴⁶	226 musicians (age range: 18–45 y)	Cross-sectional	Past-year use: 57%	Marijuana, psychedelic drug, cocaine, prescription drug, and tobacco use, binge drinking, and alcohol-related problems	Use associated with prescription drug misuse, binge drinking, and social problems related to alcohol use ^a
Peacock et al. (2013) ⁴⁷	28 young adults (age range: 18–25 y)	Experimental, within subjects	N/A	Laboratory measure of risk-taking	Small but significant relationship between energy drink condition and risk-taking task
Skewes et al. (2013) ⁴⁸	298 college students	Cross-sectional	39% weekly use	Hazardous alcohol use, alcohol-related problems, symptoms of alcohol dependence, alcohol use motives	Use associated with hazardous alcohol use, alcohol-related problems, alcohol dependence, and coping and enhancement motives
Spierer et al. (2014) ⁴⁹	407 college and graduate students	Cross-sectional	21% high users (at least three times a week)	Risky driving behaviors, tobacco, anabolic steroid, and illicit drug use, sports-related risks	Use associated with increased likelihood of driving after drinking to inebriation and riding with a drunk driver
Stasio et al. (2011) ⁵⁰	107 college students	Cross-sectional	Past-week use: 57%	Anxiety, sleep quality	Use accounted for 29% and 20% of variance in anxiety and sleep quality, respectively. ^a
Trapp et al. (2014) ⁵¹	1,234 young adults (age range: 18–22 y)	Cross-sectional	48% monthly use	Alcohol, cigarette, illicit drug use	Monthly use associated with increased alcohol consumption, cigarette smoking, use of ecstasy and marijuana, and the number of illicit drugs used
Velazquez et al. (2012) ⁵²	585 college students (underclassmen)	Cross-sectional	Past-month use: 40% Past-week use: 18%	Alcohol use, heavy drinking, mixing alcohol and energy drinks	Use associated with greater risk of all behaviors studied
Woolsey et al. (2014) ⁵³	267 college and graduate students	Cross-sectional	Past-year use: 83%	Nonmedical use of prescription stimulants	Use significantly associated with nonmedical prescription stimulant use

^a Controlled for other types of caffeine use.

Another study of college students reported that approximately one-third of past-month energy drink users had consumed the beverage mixed with alcohol.⁵² Frequency of energy drink use was also associated with alcohol quantity consumed during a single event. A study of young adults in Australia⁵¹ also found that alcohol quantity was associated with consuming energy drinks at least monthly. In another study, Miller⁴⁵ found that the frequency of energy drink use and alcohol problems were positively associated for white but not black undergraduates.

A study of musicians between the ages of 18 and 45 years found that the frequency of energy drink consumption was positively associated with binge drinking and alcohol-related social problems, even when controlling for demographic variables, sensation-seeking, impulsivity, and other types of caffeine use.⁴⁶

Other substance use has also been associated with the consumption of energy drinks, including marijuana, tobacco, and nonmedical use of prescription drugs.^{43,45,46,53} Woolsey et al.⁵³ found that past-month frequency of energy drink use was associated with nonmedical use of prescription stimulants, with 22.2% of the consumers using prescription stimulants for nonmedical purposes. Miller⁴⁵ found that consumption of energy drinks was associated with nonmedical use of prescription drugs among white, but not black, undergraduates. In another study, Miller and Quigley⁴⁶ also found that energy drink consumption was associated with nonmedical prescription drug use even when controlling for other types of caffeine use. Trapp et al.⁵¹ reported that consuming energy drinks at least monthly was associated with using ecstasy and marijuana, as well as the number of illicit drugs used.

Several other risk behaviors have been linked to energy drink consumption. Miller⁴⁵ found that sexual risk-taking (e.g., unprotected intercourse, having intercourse under the influence of alcohol or other drugs), participating in extreme sports, seatbelt omission, and taking risks on a dare were more common among high-frequency (at least once a week) energy drink consumers than low-frequency consumers. Another study of college students found that past-week consumption of caffeine-containing energy drinks accounted for 29% and 21% of the variance in anxiety and sleep disturbances, respectively, when controlling for other types of caffeine use.⁵⁰ A study of students at a predominantly minority university reported that energy drink consumption was associated with drunk driving and riding in a car with an inebriated driver.⁴⁹

One experimental study has been conducted on risk-taking behaviors related to energy drink consumption.⁴⁷ Participants attended four sessions. They were randomly assigned to consume one of four beverages at each session

in a counterbalanced order: a caffeine-containing energy drink, alcohol, a caffeine-containing energy drink mixed with alcohol, or a placebo beverage. Doses of alcohol and caffeine were based on body weight. After consuming the beverages, participants completed the Balloon Analogue Risk Task, which is a laboratory measure of risk-taking. A small but significant increase in risk-taking was seen only among participants who had consumed the nonalcoholic caffeine-containing energy drink.

The only prospective study conducted to date on the relationship between energy drink use and risk-taking behavior was guided by prior research suggesting that use of caffeine might exacerbate the underlying vulnerability to the use of other substances. Arria et al.⁴³ examined the prospective relationship between use of energy drinks during the second year of college and the risk for other forms of drug use during the subsequent year, after adjusting for prior use of each drug, demographic characteristics, and the use of other types of caffeine. The results showed that after adjustment for these variables, energy drink users were more likely to initiate nonmedical use of prescription stimulants and analgesics and they increased the frequency with which they smoked tobacco. The adjusted odds ratio associated with energy drink use for incident stimulant and analgesic use were 2.05 and 1.46, respectively.

The consumption of alcohol mixed with energy drinks has been linked to acute health risks and serious alcohol-related consequences.^{54–60} For further discussion of the consumption of alcohol mixed with energy drinks, see Marczynski et al.⁶¹ in this issue.

Among adolescents, Terry-McElrath et al.²² found that the consumption of energy drinks and energy shots is associated with past-month frequency of alcohol, cigarettes, marijuana, and amphetamine use among eighth, tenth, and twelfth graders, even after adjusting for demographic variables.

KNOWLEDGE GAPS

The analyses of MTF data presented here show that almost one in three secondary school students in the United States reported recent consumption of an energy drink. Data on energy drink consumption from Canadian adolescents shows wide variation by province, with estimates ranging from 57.2% to 64.6% for adolescents consuming energy drinks during the past year.⁶²

This high prevalence of energy drink consumption underscores the need to demonstrate the safety of consuming these beverages, especially for individuals between the ages of 13 and 18 years. As mentioned above, the amount of caffeine per serving and the concentrations of caffeine among the beverages in this class vary

widely.^{6,7} The acute and long-term health consequences of such consumption are not yet fully known.

Research is needed to develop more comprehensive assessment methods for energy drink and energy shot consumption. Despite the methodological strengths of the MTF survey, including its large sample size and its national representation, only a few questions were asked about the use of energy drinks and energy shots. Because of this, the results cannot provide sufficient information about patterns of use, specific products consumed, contexts, or consequences. It would be useful to know, for example, the proportion of youth that have used various types of energy drinks in a defined time period, such as the past year or the past month, in order to more accurately estimate how much caffeine is being consumed by adolescents. Among users, assessments are needed that can reliably quantify the amounts of the beverages consumed (e.g., typical, maximum, minimum) and how regularly consumption occurs. Given the concerns regarding the effects that ingesting high doses of caffeine can have on acute cardiovascular functioning, and during physical activity, future measures should attempt to characterize patterns of energy drink use (e.g., acute, chronic) and the contexts in which they are used (e.g., during exercise or sporting activities), particularly since marketing messages for energy drinks often involve associations with physical activity and sporting events.^{18,63}

At a fundamental level, it is important to understand how these beverages are being incorporated into the usual dietary intake of adolescents. It is possible that these drinks are replacing other beverages (e.g., water, soda, sports drinks), but they might, alternatively, be consumed in addition to other types of beverages. Concerns have been raised about the dietary choices that adolescents and young adults make, including the types of nutritional supplements and beverages they consume.^{64,65} Recent data suggest that caffeine intake among children and adolescents in the United States has remained steady during the last decade, but the proportion of caffeine intake that comes from energy drinks and coffee is increasing.⁶⁶ The extent to which energy drink consumption might be contributing to weight gain is an aspect that is not as well understood as for other sugar-sweetened beverages.⁶⁷ The data presented here show that few youth report consuming energy shots alone; instead, energy shots are consumed in addition to larger-volume energy drinks. Although data from the MTF surveys do not differentiate between sugar-containing and sugar-free energy drinks, some of these beverages contain substantial amounts of sugar in addition to caffeine. It will be important for future research to understand the extent to which energy drink consumption is a source of “empty calories” in the adolescent diet, and therefore a potential target for obesity prevention strategies. Malinauskas et al.⁵ reported

that 74% of college students who consumed energy drinks drank sugar-containing versions, with females being over-represented among individuals who consumed sugar-free versions.

In contrast to the health concerns about the cardiovascular effects of energy drinks that have been raised for several years, a newer concern relates to the possible effects of high levels of caffeine on the developing brains of adolescents.^{27,68,69} A limit of 2.5 milligrams per kilogram of caffeine per day has been suggested for children.⁶⁸

Specific subgroups appear to be at increased risk for consuming excessive caffeine. Namely, eighth graders were both more likely to have consumed an energy drink and to have consumed greater quantities of such beverages and energy shots than their older counterparts. Similarly, Hispanic youth were more likely to consume energy drinks and energy shots than other racial/ethnic groups. No data are available to shed light on possible contributory factors underlying this observed subgroup variation. Adolescents begin to make more autonomous dietary choices during this time, and personal preference begins to play a larger role.²⁴ Although parents’ influence on food choices decreases throughout this period, parental modeling still plays a role in determining adolescents’ food choices.^{24,70} For example, in one study of adolescent consumption of soft drinks, adolescents were approximately three times more likely to consume soft drinks regularly if they reported that their parents also consumed them regularly.⁷⁰ Taste preference, peer habits, habit strength, and mass media have also been identified as important influences on the food and beverage choices of adolescents.^{70–73} While it is tempting to speculate that differences in family modeling of dietary practices or targeted marketing practices might underlie these differences, future research is needed to fully explain different patterns of consumption.

Little research has been conducted to understand patterns of energy drink use among high-risk populations, such as young individuals with cardiovascular abnormalities. No data are available to evaluate the safety of consuming highly caffeinated energy drinks concurrently or simultaneously with stimulant medications and/or illicit substances used by adolescents and young adults.

CONCLUSION

With respect to the association between energy drink consumption and risk-taking behavior, the studies reviewed herein consistently demonstrate the existence of an association. However, more research is needed to clarify the nature of the observed relationship. For example, it is not entirely clear whether the association

stems from a general increased propensity for risk-taking behavior among energy drink users or whether energy drinks potentiate risk-taking among users. A few studies adjusted statistically for measures of general risk-taking propensity still found strong associations between energy drink use and alcohol-related problems.^{44,46} Further research is needed to understand the extent to which caffeine use during adolescence potentiates the reinforcing properties of other substances, especially because it is a period of rapid brain development.^{31,74} Additionally, more longitudinal research is needed to understand the temporal relationship between energy drink use and risk-taking behaviors. The one prospective study conducted to date observed a relationship between energy drink consumption and the incident or “new” use of nonmedical prescription stimulants and analgesics, even after statistical adjustment for other indicators of risk-taking behavior.⁴³

Given other research suggesting that adolescents are more likely to experience the rewarding properties of substances,⁷⁵ it is important to understand if high levels of caffeine early in adolescence might be related to increased risk for use of other psychoactive substances later in life.^{36,37} It is clear that neurobiological changes during adolescence partially explain why adolescents are more likely than older individuals to engage in risk-taking behavior^{76–78} and perhaps less likely to fully recognize the consequences of such behavior. How the use of caffeine and energy drinks fits into the sequence of underage alcohol use and the use of other drugs among adolescents requires further inquiry.

It is possible that energy drink consumption during the developmental periods of adolescence and young adulthood potentiates natural risk-taking behaviors of young people due to the stimulating pharmacological effects of caffeine. This possibility raises questions about the appropriateness of marketing and selling highly caffeinated energy drinks to adolescents because they might be especially susceptible to the potentiating effects of energy drink use on risk-taking behavior. More research is warranted to fully understand the relationship between energy drink use and risk-taking behavior and how the dose and pattern of caffeine consumption might mediate the relationship. Resolving these issues based on scientific evidence is needed to promote and protect adolescent and young adult health and safety.

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