

Published in final edited form as:

Nutr Rev. 2014 October ; 72(0 1): 87–97. doi:10.1111/nure.12129.

Energy drink use and high-risk behaviors: Research evidence and knowledge gaps

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Abstract

Sales of caffeine-containing energy drinks (CCEDs) have increased rapidly since their introduction to the marketplace. Despite the health concerns raised about highly caffeinated CCEDs, surprisingly little data are available to estimate the prevalence of use. This paper presents the results of secondary data analyses of a nationally representative dataset of US schoolchildren. Approximately one-third of students are recent CCED users with substantial variation by age, sex, and race/ethnicity. Among the health and safety concerns related to CCED use is the possibility of potentiation of risk-taking behaviors. A review of the research reveals that although there appears to be a strong and consistent positive association between CCED use and risk-taking behavior, all but one study have used cross-sectional designs, limiting their ability to make inferences about the temporal nature of the association. More research is needed to understand the nature of this association and how CCEDs might impact adolescent health and safety, especially given the high prevalence of use among youth.

Keywords

caffeine; energy drinks; energy shots

INTRODUCTION

Although no formal definition has been proposed, beverages labeled and marketed as energy drinks comprise a heterogeneous beverage category, most of which contain caffeine and a variety of other ingredients, including guarana, taurine, and B vitamins.^{1,2} Several types of caffeine-containing energy drinks (CCEDs) are 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 in these beverages, both in amount and in concentration. The amount of caffeine varies considerably among CCEDs, ranging from 50 to 500 milligrams per container,⁶ with some containers containing more than a single

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DECLARATION OF CONFLICT OF INTEREST

The authors have no relevant conflicts of interest to declare.

serving.⁷ Energy shots come in smaller-sized containers, typically less than three ounces. The caffeine concentration in energy shots differs by product, with some products containing in excess of 100 milligrams per fluid ounce.⁶ Currently no maximal limit on caffeine is imposed by the US Food and Drug Administration for either CCEDs or energy shots. In contrast, the maximal limit on caffeine in a cola-type beverage is 71 milligrams per 12 ounce serving.⁸

CCEDs 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 CCEDs and energy shots constitute one of the fastest growing segments of the beverage market, with sales in the US expected to increase from \$12.5 billion in 2012 to \$21.5 billion in 2017.⁹

Along with the rise in popularity of CCEDs has been an increase in reports of emergency department visits related to CCED use. Namely, from 2007 to 2011, there was an estimated two-fold increase in the number of individuals presenting to emergency departments after consuming a CCED, from 10,068 in 2007 to 20,783 in 2011.¹⁰ A majority of these individuals were between 18 and 39 years old, with 42% using a substance in addition to a CCED. In 2011, 1,499 adolescents ages 12 to 17 were admitted to the emergency department following consumption of a CCED. Multiple cases in which consumption of CCEDs 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} Data on hospitalizations resulting from CCED use are not systematically collected. Recent concerns about possible cardiovascular effects from high levels of caffeine in CCEDs 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 CCEDs in the diets of children,¹⁷ and the American Medical Association issued a resolution to ban the marketing of CCEDs to individuals under the age of 18.¹⁸

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 CCED consumption. In 2010, the National Health Interview Survey included a supplement containing one question on CCEDs: "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 CCEDs as part of a 24-hour dietary recall on beverages, and provides example cards of energy beverages, but does not specifically inquire about their consumption.²⁰

One of the most widely used surveys to measure the health-risk behaviors of American school children is the NIH-funded Monitoring the Future (MTF) Survey, which began asking about CCEDs in 2010. Estimates of consuming alcohol containing caffeine are available in the MTF reports since 2011 and indicated that 10.9%, 19.7%, and 26.4% of eighth, tenth, and twelfth graders consumed caffeinated alcoholic beverages during the past year, respectively.²¹ For college students and young adults ages 19 to 28, these estimates are

even higher (33.8% and 36.7%, respectively). Although the data are publicly available, the annual MTF reports have not included estimates of consuming CCEDs and energy shots without alcohol. An analysis of MTF data on CCEDs and energy shots by Terry-McElrath, O'Malley, and Johnston²² found an association between CCED and energy shot frequency and substance use; however, that study analyzed CCED and energy shot use as one variable, rather than analyzing use of the products separately. Additionally, that study did not describe subgroup variation of CCED or energy shot use by race or grade level, and did not report data on quantity of CCEDs consumed.

It is important to understand the extent to which CCEDs are becoming a part of the adolescent and young adult diet. The nutritional requirements of adolescence, defined as the period between the ages of 13 and 18, 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

To our knowledge, no research has specifically focused 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 raised about possible cardiovascular effects of consuming high levels of caffeine in CCEDs,^{7,13-16} other research studies have pointed to an association between CCED consumption 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 CCEDs 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.

In this paper, we report prevalence estimates of CCED and energy shot use by grade, gender, and race/ethnicity from secondary data analyses of the MTF dataset. We complement these findings with a summary of results from studies utilizing college student and adult samples. The second purpose of this paper is to summarize research on the link between CCED use and various forms of risk-taking behavior.

CCED USE DURING ADOLESCENCE: FINDINGS FROM THE MONITORING THE FUTURE (MTF) SURVEY

Data from MTF are available for public use via the National Addiction and HIV Data Archive Program.³⁹ To estimate the prevalence of CCED consumption, we analyzed data from the 2010 and 2011 surveys, the most recent data available. 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 in SPSS⁴¹ to estimate the prevalence of CCED use and examine variation 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 CCEDs 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 non-alcoholic 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 CCEDs. Ordinal responses to the original survey question, “About how many (if any) energy drinks do you drink per day on average?” were recoded 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 time frame was specified in the original question; therefore, we operationalized current use 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 CCED 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 that they used CCEDs. One striking observation is that eighth graders were more likely to consume CCEDs compared with tenth and twelfth graders. For every grade, males were more likely than females to use CCEDs. Black individuals had the lowest prevalence of CCED 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 was less prevalent than for CCEDs, with 12%, 9%, and 10% of eighth, tenth, and twelfth graders using energy shots, respectively. While gender differences were similar to what was observed for CCEDs, 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 CCEDs and energy shots were asked separately, it was possible to examine what proportion of students consumed both types of products. As shown in the lowest layer of bars in Figure 2, between 8% and 12% of students consumed both CCEDs and energy shots. Interestingly, almost all energy shot users also consumed CCEDs. Between 20% and 24% consumed CCEDs, 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 to 2011.

Table 1 shows data on the daily use of CCEDs and energy shots. Eighth graders showed the highest prevalence of daily use for both CCEDs (18%) and energy shots (7%). Consistent with results from Figures 1a and 1b, Hispanic eighth graders stood out again as the subgroup with the highest prevalence of daily use of CCEDs (22%) and energy shots (11%).

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 prevalence of use and daily use. For instance, 24% of CCED consumers in the eighth grade were drinking two or more per day, compared with 16% and 13% of their counterparts in tenth and twelfth grade, respectively. This trend was evident in all six of the subgroups we examined, but was perhaps most pronounced among Hispanics, with nearly a three-fold difference in two-a-day use between eighth and twelfth graders (30% vs. 11% drinking two or more CCEDs 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.

PREVALENCE AMONG COLLEGE STUDENTS

The prevalence of CCED use among college students is presented in Table 3. As can be seen, CCED use varies substantially among the samples studied, primarily because of the different time frames used to assess consumption. Both Arria et al.⁴³ and Miller⁴⁴ reported that 10% of college students in their samples were “weekly” consumers. Others reported higher estimates for weekly consumption.⁴⁵ In a study about CCED consumption patterns Malinauskas et al.⁵ found that 51% of college students consumed more than one CCED each month in an average month during the past semester. Across the various studies, even with the differences in methodology, CCED use appears to be even more common among college students than younger adolescents.

RELATIONSHIP BETWEEN CCED USE AND RISK-TAKING BEHAVIORS AMONG COLLEGE STUDENTS

Several observational studies and one experimental study have examined the association between CCED use 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- to 45-year-old musicians. All but one of the studies have gathered data using cross-sectional survey designs, where questions about CCED consumption were asked along with questions about risk-taking behaviors. The results of these studies are consistent and clearly show that CCED users are more likely to engage in risk-taking behavior.

Many forms of risk-taking behavior have been investigated, including marijuana, tobacco, other forms of drug use, sexual risk-taking, and seat belt omission. CCED consumption, regardless of mixing with alcohol at the time of consumption, has been associated with alcohol-related outcomes. In a study of 298 college students, Skewes et al.⁴⁵ found a positive association between the typical number of CCEDs 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, CCED consumption 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 CCED frequency 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.⁴³ found a positive relationship between the frequency of CCED 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, 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 CCED use and alcohol dependence might be interrelated in a meaningful way, rather than merely co-occurring due to shared risk factors such as a general propensity to drink more alcohol.

Another study of college students reported that approximately one third of past-month CCED users had mixed CCEDs and alcohol during the past month.⁴⁶ CCED use frequency was also associated with alcohol quantity consumed during a single event. A study of Australian young adults⁴⁷ also found that alcohol quantity was associated with consuming CCEDs at least monthly. In another study, Miller⁴⁴ found that CCED frequency and alcohol problems were positively associated for White but not Black undergraduates.

A study of musicians ages 18 to 45 found that the frequency of CCED 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.⁴⁸

Other substance use has also been associated with the consumption of CCEDs, including marijuana, tobacco, and nonmedical use of prescription drugs.^{44,48-50} Woolsey et al.⁵⁰ found that past-month frequency of CCED use was associated with nonmedical use of prescription stimulants, with 22.2% of CCED consumers using prescription stimulants nonmedically. Miller⁴⁴ found that CCED consumption was associated with nonmedical use of prescription drugs among White, but not Black undergraduates. In another study, Miller and Quigley⁴⁸ also found that CCED consumption was associated with nonmedical prescription drug use even when controlling for other types of caffeine use. Trapp et al.⁴⁷ reported that consuming CCEDs 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 CCED consumption. Miller⁴⁴ 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) CCED consumers than low-frequency consumers. Another study of college students found that past-week consumption of CCEDs accounted for 29% and 21% of the variance in anxiety and sleep disturbances, respectively, when controlling for other types of caffeine use.⁵¹ A study of students at a predominantly minority university reported that CCED consumption was associated with drunk driving and riding in a car with an inebriated driver.⁵²

One experimental study has been conducted on risk-taking behaviors related to CCED consumption.⁵³ Participants attended four sessions. They were randomly assigned to consume one of four beverages at each session in a counterbalanced order: a CCED, alcohol, a CCED 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, a laboratory measure of risk-taking. A small but significant increase in risk-taking was seen only among participants who had consumed the non-alcoholic CCED.

The only prospective study conducted to date on the relationship between CCED 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.⁴⁹ examined the prospective relationship between CCED use 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, CCED 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 CCED use for incident stimulant and analgesic use were 2.05 and 1.46, respectively.

The consumption of alcohol mixed with CCEDs has been linked to acute health risks and serious alcohol-related consequences.⁵⁴⁻⁶⁰ For further discussion of the consumption of alcohol mixed with CCEDs, see Marczynski et al. in this issue.

Among adolescents, Terry-McElrath et al.²² found that the consumption of CCEDs 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.

CONCLUSION AND KNOWLEDGE GAPS

Our analyses of MTF data show that almost one in three secondary school students in the US recently consumed a CCED. Data on CCED consumption from Canadian adolescents shows wide variation by province with estimates ranging from 57.2% to 64.6% on adolescents consuming CCEDs during the past year.⁶¹

The high prevalence of consumption of CCEDs observed in the current study underscores the need to demonstrate the safety of consuming these beverages, especially for individuals between the ages of 13 and 18. As mentioned earlier, the amount of caffeine per serving and the concentrations of caffeine among this beverage class varies widely.^{6,7} The acute and long term health consequences of such consumption are not known.

Research is needed to develop more comprehensive assessment methods for CCED and energy shot consumption. Despite the methodological strengths of the MTF survey, including its large sample size and its national representativeness, only a few questions were asked about CCEDs 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 the proportion of youth that have used various types of CCEDs in a defined time period, such as the past year or the past month, to more accurately estimate how much caffeine is being consumed by adolescents. Among users, assessments are needed that can reliably measure how much is consumed (e.g., typical, maximum, minimum) and how regularly consumption occurs. Given the concerns regarding ingesting high doses of caffeine on acute cardiovascular functioning, and during physical activity, future measures should attempt to characterize CCED use patterns (e.g., acute, chronic) and the contexts during which they are used (e.g., during exercise or sporting activities). CCED marketing messages often involve associations with physical activity and sporting events.^{18,62}

Moreover, it is important to understand how these beverages are being incorporated into the usual dietary intake of adolescents. It is possible that they are replacing other beverages (e.g., water, soda, sports drinks) or alternatively, they might 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.^{63,64} Recent data suggest that caffeine intake among children and adolescents in the US has remained steady during the last decade, but the proportion of caffeine intake that comes from energy drinks and coffee is increasing.⁶⁵ The extent to which CCED consumption might be contributing to weight gain is not as well understood as for other sugar-sweetened beverages.⁶⁶ Our data show that few youth report consuming energy shots only, but rather consume them in addition to larger-volume CCEDs. Although data from MTF does not differentiate between sugar-containing and sugar-free CCEDs, some CCEDs contain substantial amounts of sugar in addition to caffeine. It will be important for future research to understand the extent to which CCED consumption is a source of “empty calories” in the adolescent diet, and therefore could be a target for obesity prevention strategies. Malinauskas et al.⁵ reported that 74% of college students who consumed CCEDs drank sugar-containing versions, with females being over-represented among individuals who consumed sugar-free versions.

In contrast to the health concerns about cardiovascular effects of CCEDs that have been raised for several years, a newer concern relates to the possible effects of high levels of caffeine on the developing brain of adolescents.^{27,67,68} A limit of 2.5 milligrams per kilogram of caffeine per day has been suggested for children.⁶⁷

Specific subgroups appear to be at increased risk for consuming excessive caffeine. Namely, eighth graders were both more likely to have consumed a CCED and to have consumed greater quantities of CCEDs and energy shots than their older counterparts. Similarly, Hispanic youth were more likely to consume CCEDs 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.^{24,69} 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.⁶⁹ Taste preference, peer habits, habit strength, and mass media have also been identified as important influences on adolescence food and beverage choices.^{69–72} 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 CCED patterns among high-risk populations, such as young individuals with cardiovascular abnormalities. No data are available to evaluate the safety of consuming highly-caffeinated CCEDs concurrently or simultaneously with stimulant medications and/or illicit substances used by adolescents and young adults.

With respect to the association between CCED 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 CCED users or whether CCEDs potentiate risk-taking among users. A few studies adjusted statistically for measures of general risk-taking propensity and still found strong associations between CCED use and alcohol-related problems.^{43,48} 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.^{31,73} Additionally, more longitudinal research is needed to understand the temporal relationship between CCED use and risk-taking behaviors. The one prospective study conducted to date observed a relationship between CCEDs and the incident or “new” use of nonmedical prescription stimulants and analgesics, even after statistical adjustment for other indicators of risk-taking behavior.⁴⁹

Given other research suggesting that adolescents are more likely to experience the rewarding properties of substances,⁷⁴ 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 behavior⁷⁵⁻⁷⁷ and perhaps less likely to fully recognize the consequences of such behavior. How caffeine and CCED use fit into the sequence of underage alcohol use and the use of other drugs among adolescents requires further inquiry.

It is possible that CCED 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 CCEDs to adolescents because they might be especially susceptible to the potentiating effects of CCED use on risk-taking behavior. More research is warranted to fully understand the relationship between CCED use and risk-taking behavior, and how dose and pattern of caffeine consumption might mediate the relationship. Resolving these issues based on scientific evidence is needed to promote and protect adolescent health and safety.

Acknowledgments

Special thanks are given to Kaitlin Hippen, the interviewing team, and the participants.

FUNDING

The investigators acknowledge funding from the National Institute on Drug Abuse (R01DA014845, Dr. Arria, PI). The National Institute on Drug Abuse played no role in the study design, data collection and analysis, manuscript preparation and revision, or publication of this manuscript. Data collection for the Monitoring the Future survey was also funded by the National Institute on Drug Abuse (R01DA001411, Dr. Johnston, PI).

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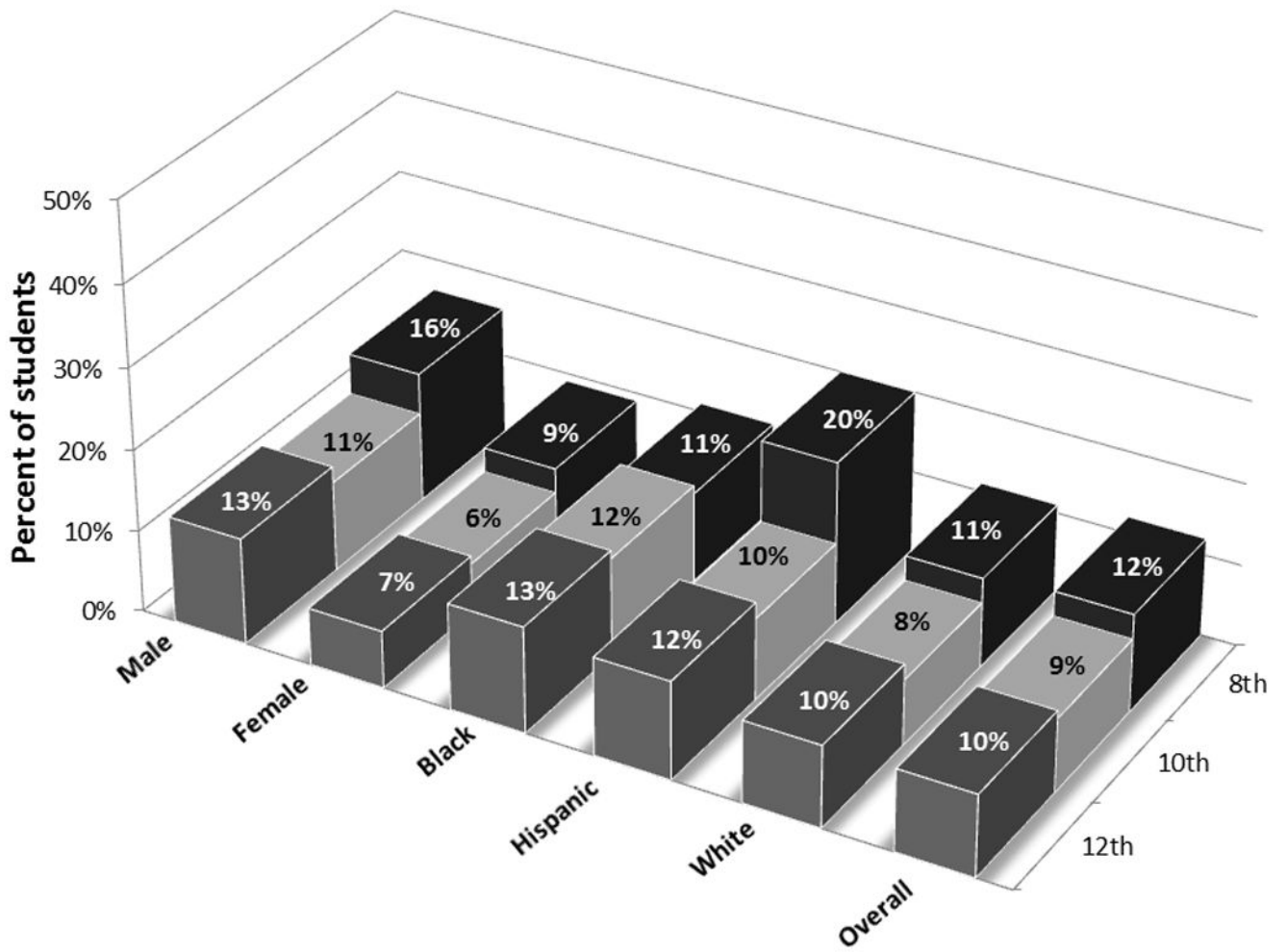
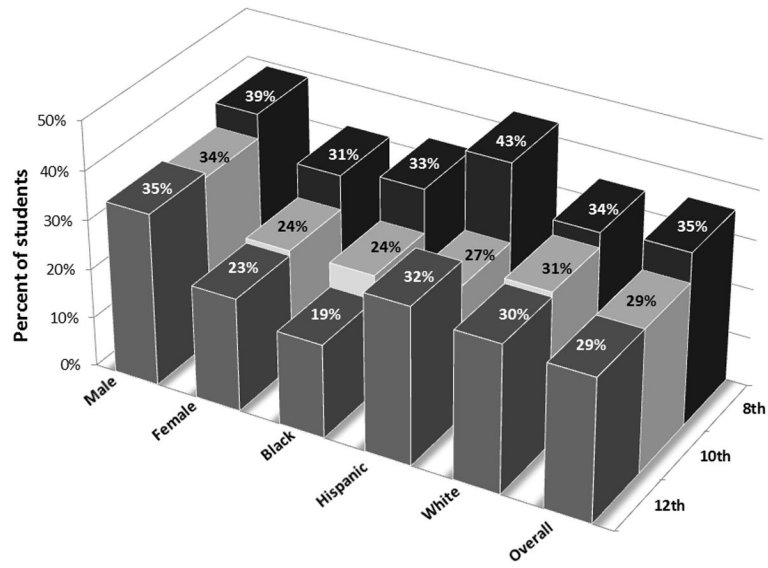


Figure 1.

Figure 1a Prevalence of recent CCED use, by gender, race/ethnicity, and grade.

Figure 1b Prevalence of recent energy shot use, by gender, race/ethnicity, and grade.

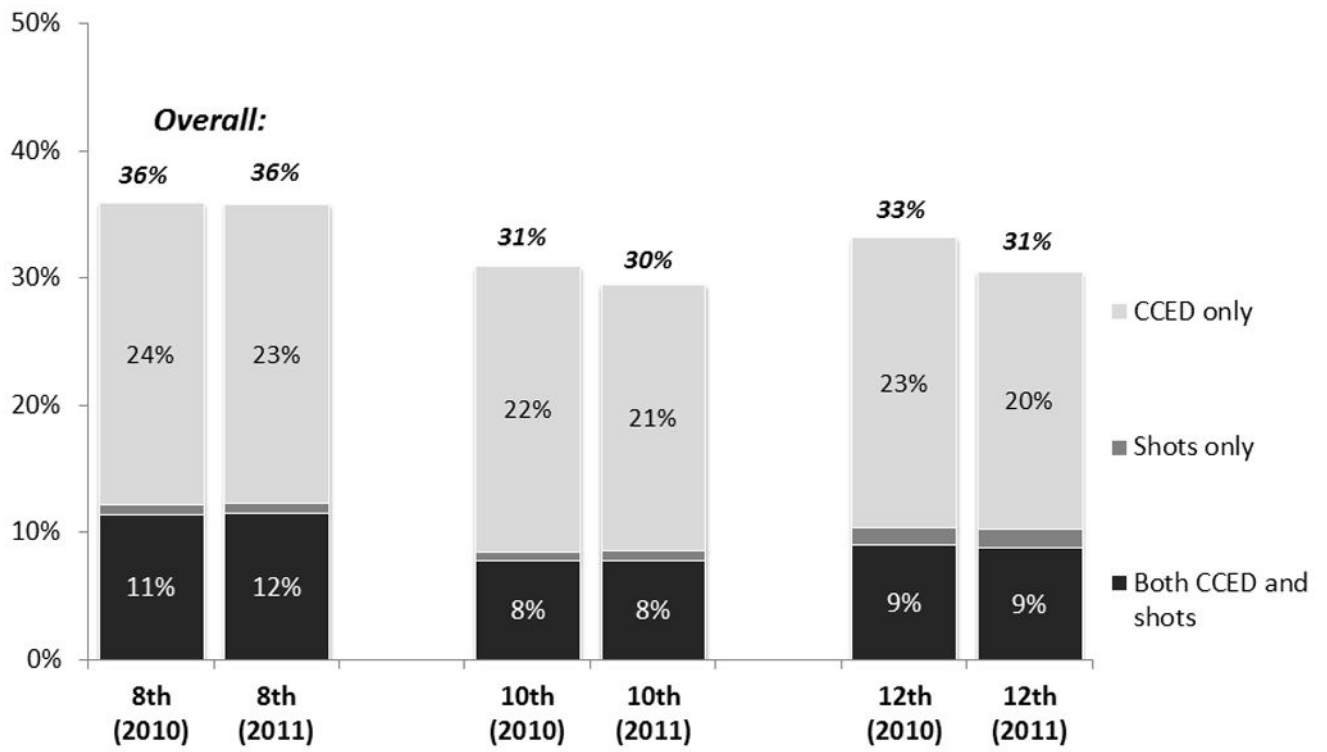


Figure 2.
Prevalence of recent use of CCEDs and/or shots, by grade and year.

Table 1Prevalence of daily use of CCEDs^a and energy shots by grade.

	CCED		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

^a Caffeine-containing energy drink

Table 2

Number of CCEDS^a and energy shots consumed per day, among users, by sex, race, and grade.

	Male			Female			Black			White			Hispanic			Total		
	8 th	10 th	12 th	8 th	10 th	12 th	8 th	10 th	12 th	8 th	10 th	12 th	8 th	10 th	12 th	8 th	10 th	12 th
Number of CCEDS ^a /day																		
<1	48.9	58.7	66.8	50.7	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	25.1	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	24.2	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
Number of energy shots/day																		
<1	45.4	49.1	64.9	43.1	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	26.1	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	30.8	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

^a Caffeine-containing energy drink

Table 3

Summary of studies on the relationship between CCED^a use and risk behaviors.

Authors	Sample	Study design	CCED prevalence	Risk behaviors studied	Results
Arria et al. (2010) ³⁹	n=1,060 college students	Prospective	Typical use: 23% (Year 2), 36.5% (Year 3)	Incident use of eight drugs	CCED use associated with incident nonmedical prescription drug use and frequency of tobacco smoking.*
Arria et al. (2011) ³⁴	n=975 college students	Cross-sectional	Past-year use: 51% less than weekly 10% weekly use	Alcohol use and related problems, alcohol dependence	CCED use associated with alcohol dependence.*
Miller (2008) ³⁵	n=602 college students	Cross-sectional	Past-month use: 38%	Marijuana, tobacco, alcohol, and prescription drug use, sexual risk-taking, seat belt omission	CCED use associated with risk-taking; race/ethnicity difference existed.
Miller et al. (2011) ³⁸	n=226 musicians ages 18 to 45	Cross-sectional	Past-year use: 57%	Marijuana, psychedelic drug, cocaine, prescription drug, and tobacco use, binge drinking, and alcohol-related problems	CCED use associated with prescription drug misuse, binge drinking, and social problems related to alcohol use.*
Peacock et al. (2013) ⁴²	n=28 young adults ages 18 to 25	Experimental, within subjects	N/A	Laboratory measure of risk-taking	Small but significant relationship between CCED condition and risk-taking task.
Skewes et al. (2013) ³⁶	n=298 college students	Cross-sectional	39% weekly use	Hazardous alcohol use, alcohol-related problems, symptoms of alcohol dependence, alcohol use motives	CCED use associated with hazardous alcohol use, alcohol-related problems, alcohol dependence, and coping and enhancement motives.
Spierer et al. (2014) ³²	n=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, and sports-related risks	CCED use associated with increased likelihood of driving after drinking to inebriation and riding with a drunk driver.
Stasio et al. (2011) ⁴¹	n=107 college students	Cross-sectional	Past-week use: 57%	Anxiety, sleep quality	CCED use accounted for 29% and 20% of variance in anxiety and sleep quality, respectively.*
Trapp et al. (2014) ⁴⁷	n=1,234 young adults ages 18 to 22	Cross-sectional	48% monthly use	Alcohol, cigarette, and illicit drug use	Monthly CCED use associated with increased alcohol quantity, being a cigarette smoker, use of ecstasy and marijuana, and the count of illicit drugs used.
Velazquez et al. (2012) ³⁷	n=585 underclassmen college students	Cross-sectional	Past-month use: 40% Past week use: 18%	Alcohol use, heavy drinking, mixing alcohol and CCED	CCED use associated with greater risk of all behaviors studied.
Woolsey et al. (in press) ⁴⁰	n=267 college and graduate students	Cross-sectional	Past-year use: 83%	Nonmedical use of prescription stimulants	CCED use was significantly associated with nonmedical prescription stimulant use.

^a Caffeine-containing energy drink

* controlled for other types of caffeine use

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