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Abstract

Background: Caffeinated energy drinks (CCEDs) are frequently consumed by adolescents aged 10-19, yet the effects of consumption on adolescent behavior are not well understood. Previous research has identified positive associations between CCED use and other substances such as alcohol and marijuana but studies among adolescents are lacking. **Methods:** We conducted a secondary analysis using data collected from the 2019 Alcohol, Drug Addition, and Mental Health Services (ADAMHS) Board/Wood County Educational Service Center's youth survey. Ten public schools in Wood County, Ohio participated (n=6,152). **Results:** CCED use was common among our sample (43.4% overall). Reported consumption increased with age and was positively associated with alcohol use and cough medicine use. Furthermore, CCED use was associated with three behavioral outcome categories: anger, delinquency, and negative mental health outcomes. **Conclusion:** Due to the ubiquity of use and associated substance use and behavioral outcomes, CCED use among youth requires more attention.

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ABSTRACT

Background: Caffeinated energy drinks (CCEDs) are frequently consumed by adolescents aged 10-19, yet the effects of consumption on adolescent behavior are not well understood. Previous research has identified positive associations between CCED use and other substances such as alcohol and marijuana but studies among adolescents are lacking. **Methods:** We conducted a secondary analysis using data collected from the 2019 Alcohol, Drug Addition, and Mental Health Services (ADAMHS) Board/Wood County Educational Service Center's youth survey. Ten public schools in Wood County, Ohio participated (n=6,152). **Results:** CCED use was common among our sample (43.4% overall). Reported consumption increased with age and was positively associated with alcohol use and cough medicine use. Furthermore, CCED use was associated with three behavioral outcome categories: anger, delinquency, and negative mental health outcomes. **Conclusion:** Due to the ubiquity of use and associated substance use and behavioral outcomes, CCED use among youth requires more attention.

Keywords: caffeinated energy drinks, CCEDs, caffeine use, substance use

INTRODUCTION

The consumption of caffeine has increased substantially worldwide in part through strategic marketing and promotion approaches of energy drinks.¹ Due to this aggressive marketing, caffeine-containing energy drinks (CCEDs) are the second most popular dietary supplement consumed by teens and young adults in the United States.² Moderate or infrequent use of CCEDs appears to indicate a low risk for healthy people; nevertheless, excessive consumption of caffeine, particularly together with other substances (alcohol and/or illicit drugs), may constitute a health hazard for adolescents and young people and/or individuals with compromised health statuses and other disorders.^{1,3,4} High levels of caffeine consumption (typically defined as >100 mg/day for adolescents) have been associated with dehydration, increased blood pressure, tachycardia, insomnia, and anxiety.^{5,6} Given these negative health outcomes, the American Academy of Pediatrics (AAP) states that CCEDs have no place in the diet of children and adolescents.⁷

Furthermore, CCEDs consumption in early adulthood has been correlated with other substance use disorders later in life.⁸⁻¹⁰ In addition to these findings, several studies proposed to explain the underlying relationships between CCEDs and substance use disorders.^{11,12} CCEDs at baseline are significantly associated with alcohol consumption years later after adjusting for risk factors such as preliminary thrill-seeking, perceived peer alcohol use, and initial perceived best friends' alcohol use.^{4,12} Additional studies add support that frequent CCEDs users at adolescence are significantly more likely to have been alcohol users, smokers, and cannabis users at late teens into young adulthood.^{11,13}

These study findings reveal a positive relationship of CCEDs and impulsive behaviors and risk taking/sensation seeking behaviors among adolescents and young adults.^{4,10,14} Additionally, CCED use and these behaviors (risk taking/sensation seeking) differ greatly as a function of sex.^{11,14} Girls are less likely to engage in sensation seeking and risk behaviors than boys and consume smaller amounts of CCEDs each day when compared with boys.^{15,17} Some potential explanations for these differences may include peer influence, social acceptability, as well as potential hormone differences between the two groups.^{15,16}

Caffeine has been defined as one of the most extensively used psychoactive substances and is one of the best-described psychostimulants, having arousal and reinforcing properties.^{3,17} These stimulating effects are the result of the aggressive obstruction of both the central and peripheral adenosine receptors.¹⁸ Like many other psychoactive substances, consistent caffeine consumption has been linked to physical dependence, with individuals demonstrating withdrawal indicators upon abstinence comprising trouble concentrating, mood disruptions, headache, fatigue, and flu-like symptoms.¹⁹ Symptoms may persist for three to nine days following the onset of withdrawal, which usually occurs 12–24 hours after abstinence. Withdrawal symptoms may be evident following abstinence from as little as 100 mg of daily caffeine intake.^{18,19} In addition to withdrawal, the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) comprises several caffeine-related diagnoses, including caffeine-induced sleep disorders, caffeine-induced anxiety, and caffeine intoxication.²⁰

Moreover, when coupled with alcohol, as was found in now-banned beverages such as Four Loko® and other caffeinated alcoholic beverages (CABs), the confounding effects of caffeine are substantial.²¹ The caffeine in CABs can disguise the effects of alcohol increasing the total amount of alcohol consumed at one sitting while increasing the likelihood of engaging in other risky behaviors such as unprotected sex and drunk driving.^{22,23} While CABs were premixed beverages sold in the 2000s, 10.6% of youth in grades 8 to 12 reported combining alcohol with caffeinated energy drinks in 2017.²⁴

Notwithstanding the possibility for adverse consequences, caffeine is well-known for being the only psychoactive substance readily accessible to, and even promoted specifically to, adolescents and youth.^{25,26} Adolescents frequently consume caffeine through soda (e.g., Pepsi, Coca-Cola), and in other non-regulated forms of 'energy' drinks (e.g., Red Bull regular or sugar free, Monster energy). They also consume caffeine in tea, coffee (caffeinated), and certain candy.⁴ The NIH-funded Monitoring the Future (MTF) Survey, which is among the most extensively used surveys gauging the health-risk behaviors of American schoolchildren, indicated that between 20% and 24% of its respondents consumed energy drinks.⁸ Of these respondents, 35% of eighth graders and 29% of both tenth and twelfth graders indicated some form of energy drinks consumption.⁸ Furthermore, Hispanic eighth graders had the highest prevalence rates (43%) while African American students reported the lowest rates [19%] regardless of grade level.⁸ While most caffeinated sodas normally contain between 20 and 60 mg of caffeine per 12-ounce serving, the concentration of caffeine contained in CCEDs usually ranges from 60 to 140 mg per 12 ounces, with the concentrations of caffeine in energy drinks being more representative of the caffeine concentration of regular coffee.^{4,5,27}

Due to the ubiquity of caffeine use and a dearth of research on the correlations of CCED use and behavioral outcomes among adolescents, the current study has three aims, which are as follows: 1) to assess the overall frequency of CCED use among adolescents aged 10-19 in Wood County, Ohio; 2) to explore associations of CCED use and other substance use, and 3) to identify correlations between CCED use and mental health and behavioral outcomes.

METHODS

Participants and Procedure

This secondary analysis used data collected from the 2019 Alcohol, Drug Addition, and Mental Health Services (ADAMHS) Board/Wood County Educational Service Center's youth survey. Ten public schools in Wood County, Ohio participated in the paper-based survey. A total of 7,573 students in grades 7 to 12 (aged 10-19) in Wood County, Ohio participated in the survey. Of these, 763 were excluded due to insincere responses (e.g., reporting use of all drugs at all times; reporting use of fake drugs; providing inconsistent responses). As gender and age were variables of interest in the study, 397 participants were excluded due to missing data on gender ($n = 360$) and/or age ($n = 37$). Moreover, due to low frequencies, participants under the age of 12 years ($n = 14$) and over the age of 18 years ($n = 6$) were removed. Finally, participants that had greater than 50% missing items on Problem Severity Scale (PSS)²⁸ were removed ($n = 241$). No significant differences were identified in the demographic characteristics of the included and excluded sample. Following the above data-cleaning procedures, the final sample consisted of 6,152 participants, 50.0% female ($n = 3,079$), with a mean age of 14.79 years ($SD = 1.75$).

Ethical Considerations

Before participating, parental consent and student assent were obtained. Students were informed that all responses were anonymous, would be kept confidential, and that participation was voluntary. Ethical approval was granted by the Wood County ADAMHS ethics committee.

Measures

Frequency of Caffeinated Energy Drink Consumption and Other Substances

Participants were asked, "During the last year, on how many occasions have you used caffeinated energy drinks (Red Bull, Rock Star, Monster?" Frequency of caffeinated energy drink consumption was measured using a Likert-style response scale of never, 1-2 times, 3-5 times, 6-10 times, 11+ times. Frequency of consumption for each of the following substances was measured using the same Like-style response scale over the past 30 days: alcohol, nicotine, marijuana, powdered cocaine, sleep/anxiety medication, steroids, Ritalin/Adderall, cough medicines, inhalants, LSD, heroin, K2, MDMA, and oxycontin/painkillers.

Mental Health and Behavioral Outcomes

Mental health and behavioral outcomes were assessed using the Problem Severity Scale (PSS).²⁸ The PSS consists of 20 items that assess common mental health-related symptoms (i.e. worthlessness, loneliness, and depression) and behavioral problems (i.e. arguing with others, getting into fights, and skipping school). Frequency of each item is measured on a 6-point Likert-style scale of not at all, once or twice, several times, often, most of the time, and all of the time over the past 30 days. Previous research²⁹ shows the PSS includes four separate factors of Aggression, Anxiety, Depression, and Delinquency with three to eight questions per factor. However, given the overlap between anxiety and depression items, this study conducted a factor analysis to examine if the number of factors could be reduced for parsimony in analyses. Results indicate that a three-factor structure is appropriate for these data: Negative Mental Health ($\alpha = .93$), Anger ($\alpha = .86$), and Delinquency ($\alpha = .72$). Thus, mental health and behavioral outcomes for the purposes of this study are conceptualized based on these three factors. Negative mental health included hurting oneself, talking or thinking about death, feeling worthless, feeling lonely, feeling anxious or fearful, worrying, feeling sad or depressed, having nightmares, and having eating problems. Anger included arguing with others, getting into fights, yelling, fits of anger, refusing to listen to authority, causing trouble, lying, and having too much energy. Delinquency included breaking rules or the law, skipping school or classes, and using drugs or alcohol.

Statistical Analysis

Data were analyzed using IBM SPSS Version 24. Descriptive statistics were conducted for all study variables to calculate frequencies. To assess gender and racial/ethnic difference in CCED consumption, gender and racial/ethnic identity were dichotomized and independent samples t-tests were conducted. Pearson correlations were conducted among frequency of CCED consumption and frequency of other substances usage. An alpha .05 was used for all analyses.

RESULTS

Frequency of CCED Consumption and Other Substances

Overall, 43.4% ($n = 2665$) of students indicated that they had consumed a CCED at least 1-2 times in the last year. Among students who consumed a CCED, age [$r(2665) = .20, p < .001$] and grade [$r(2575) = .20, p < .001$] were positively associated with consumption, suggesting that consumption increases with age. By age 16, about half of students (50.1%, $n = 560$) reported drinking a CCED at least 1-2 times in the last year (see Table 1). Similarly, by grade 11, about half of students (49.2%, $n = 539$) reported drinking a CCED at least 1-2 times in the last year. Gender differences in consumption were also observed, $t(6049.68) = 7.81, p < .001$. Males ($M = 1.16, SD = 1.49$) reported more frequent consumption than females ($M = 0.88, SD = 1.32$).

Regarding race/ethnicity, there were no significant differences in CCED consumption between white students and students of color, $t(6137) = 1.62$, $p = .11$.

Table 1. Frequencies of Demographic Characteristics by CCED Consumption

Variable	No CCED	At least 1-2 CCED/year
	n	n
Age		
12	541	194
13	640	348
14	577	409
15	578	488
16	558	560
17	452	521
18	128	145
Grade		
7	689	284
8	603	355
9	581	419
10	552	497
11	556	539
12	400	481
Sex		
Male	1610	1457
Female	1864	1208
Race/Ethnicity		
White	2833	2105
Black or African American	84	54
Latino	148	150
Asian	96	34
Pacific Islander	1	8
Middle Eastern	18	16
Native American	14	21
Multicultural	115	129
Not listed	63	48

Note: Percentages may not equal 100% due to rounding and/or non-reported responses.

Most students who indicated that they consumed at least some caffeinated energy drinks (at least 1-2 times) in the last year reported that they had never used a vaping device (52.5%, $n = 1397$) or marijuana (70.7%, $n = 1878$) but had used alcohol (55.3%, $n = 1472$). Among those students that said they had consumed some alcohol and caffeine, over half of students (69.2%, $n = 1018$) had tried alcohol by age 13 or 14.

CCED Consumption and Other Substance Use

Among students who indicated that they consumed CCEDs and other substances, Pearson correlations were conducted among consumption and non-prescribed substance usage (i.e., alcohol, marijuana, powdered cocaine, sleep/anxiety medication, steroids, Ritalin/Adderall, cough medicines, inhalants, LSD, heroin, K2, MDMA, oxycontin/painkillers (see Table 2 for frequencies and Table 3 [in APPENDIX] for all correlation coefficients). CCED consumption was positively associated with alcohol consumption [$r(1161) = .17$, $p < .001$] and cough medicine usage [$r(344) = .18$, $p < .001$] while consumption was negatively related to inhalant usage [$r(136) = -.20$, $p = .02$].

Table 2. Frequencies of Substance Use in the Past Year among Students who CCEDs

Variable	No Substance Use		Some Substance Use ¹	
	n	%	n	%
Alcohol	1498	56.3	1161	43.7
Powdered cocaine	2617	98.2	48	1.8
Marijuana	1958	73.6	702	26.4
Cough medicine	2321	87.1	344	12.9
Ritalin/Adderall	2529	95.0	134	5.0
Sleep/anxiety medication	2435	91.4	229	8.6
Methamphetamines	2634	98.8	31	1.2
Steroids	2628	98.8	32	1.2
Inhalants	2529	94.9	136	5.1
LSD	2555	95.9	109	4.1
Heroin	2645	99.3	19	0.7
K2	2633	98.9	30	1.1
MDMA	2608	97.9	55	2.1
Oxycontin/painkillers	2446	92.0	214	8.0

Note. Percentages may not equal 100% due to rounding and/or non-reported responses.¹Some substance use is defined as consuming at least 1-2 times in the past 30 days

CCED Consumption and Behavioral Outcomes

Among students who indicated they consumed a CCED in the last year, Pearson correlations were conducted between consumption and behavioral outcomes (i.e., anger, delinquency, and negative mental health). CCED consumption was positively related to all three factors: increased anger [$r(2665) = .18, p < .001$], delinquency [$r(2665) = .23, p < .001$], and negative mental health outcomes [$r(2664) = .14, p < .001$].

DISCUSSION

Reports of CCED consumption were high among adolescents aged 12-18 in our sample (43.4% overall). While other research has shown that CCED use is highest in eighth grade and tends to decrease in 11th and 12th grade,⁸ our results indicate CCED consumption was positively correlated with age. Of note, age 16 was the first age at which there was a higher percentage CCED consumers versus non-consumers. Differences between the results of our study and other research may be due to variances in item wording since our data asked about CCED consumption over the past year versus daily consumption as other studies have examined.⁸ Furthermore, participants who drank CCEDs were mostly male, which is consistent with other literature.^{4,15}

Overall, frequency of use for other substances was low in our sample and considerably low for cocaine, methamphetamines, steroids, heroin, and K2, regardless of CCED use. Alcohol was the most frequently reported substance used among CCED consumers (43.7%). When exploring associations between CCED use and other substances, CCEDs were significantly correlated with alcohol use and cough medicine consumption. Other research has also found significant associations between CCED consumption, alcohol, and marijuana use.^{11,13} While our study was cross-sectional and could not identify patterns of use later in life, previous studies have reported that CCED use in early life predicts the use of other substances, such as alcohol, into young adulthood.¹⁰⁻¹³ Since CCEDs are frequently conceptualized as being higher risk than other caffeinated beverages such as tea or soda, exploring patterns of co-use with other substances is necessary to target prevention campaigns appropriately.

In our study, all three behavioral factors (anger, delinquency, and negative mental health outcomes) were positively associated with CCED use. While the negative physical effects of CCED consumption, such as tachycardia, dehydration, and insomnia have been documented by other researchers,^{5,6} our study goes one step further in identifying additional behavioral and mental health outcomes that may be associated with CCED use among adolescents. It is well established that substance use is associated with negative mental health outcomes and risk-taking behavior³⁰ yet few studies have included CCEDs in their list of substances that may be associated with such outcomes. Moreover, the Youth Risk Behavior Survey, which is administered by the Centers for Disease Control and Prevention (CDC) to high school youth every two years does not include questions about CCED use or CABs in their list of substances or other drugs, giving the impression that they are less risky or of less concern than other substances.³¹ Due to the lack of national data, future research among youth should focus on how CCEDs differ from other substances in terms of risk-taking behaviors and negative behavioral outcomes. Furthermore, since few studies have used causal designs to examine the effects of CCEDs on behavior in adolescents, interventional studies examining CCED use and feelings of negative mental health and expressions of anger are warranted.

Limitations

This study is limited due to several factors. One, since the survey was cross-sectional in nature, no causation can be inferred. Second, since frequency data were self-report and the administration of the survey occurred during school hours, there is a potential for participant bias. Third, taking into account the wording of the survey items, it is possible that students who indicated they had consumed a CCED only 1-2 times in a year were just trying the substance. Given the potential health hazards associated with CCED use and the AAP's firm stance that CCEDs should have no place in an adolescent's diet, we believe any consumption warrants further exploration. Finally, due to the lack of diversity in our sample, generalizability to other populations is limited.

CONCLUSION

CCED use was associated with three behavioral outcome categories: anger, delinquency, and negative mental health outcomes. Due to the ubiquity of use and associated substance use and behavioral outcomes, CCED use among youth requires more attention.

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APPENDIX

Table 3. Correlations Between Frequency of CCED Use and Other Substance Use

	Correlations														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. CCED	1														
2. Alcohol	.17**	1													
3. Marijuana	.07	.32**	1												
4. Cocaine	.06	.09	-.16	1											
5. Methamphetamines	.01	-.16	.11	.90**	1										
6. Sleep/anxiety medicine	-.09	-.05	.08	.35	.46	1									
7. Ritalin/Adderall	.13	.21*	.02	.05	-.22	.30*	1								
8. Cough medicine	.18**	-.03	-.05	-.03	-.27	.11	.11	1							
9. Inhalant	-.20*	.01	.28**	.12	-.05	.18	.13	.01	1						
10. Steroid	-.03	.35	.01	.39	.10	.45	.58	-.08	.13	1					
11. LSD	.05	.03	.04	.28	.13	.40**	.33*	.19	.14	.66	1				
12. Heroin	.11	.15	.14	.38	.19	.63	-.73*	.43	.59*	.01	.20	1			
13. K2	-.14	-.12	.05	.82*	.04	.21	.27	.04	.09	.33	.19	.01	1		
14. MDMA	.03	.07	.20	.46	.15	.40*	.40*	.32	.44*	.40	.59**	.61	-.33	1	
15. Oxycontin/painkillers	-.07	-.05	.05	-.04	.12	.27*	.06	.30**	.37*	.22	.41*	.24	.27	.46*	1

*p < .05, **p < .01