Caffeinated energy drink consumption and predictors of use among secondary school students over time in the COMPASS cohort study

Alexandra E. Butler*, Wei Qian, Scott T. Leatherdale

School of Public Health and Health Systems, University of Waterloo, Waterloo, Canada

ABSTRACT

Consumption of caffeinated energy drinks (CED) by youth is a public health priority, given the lack of regulation and evidence for both short and long-term health effects of CED use. Considering the potential risks associated with excessive caffeine consumption, this paper examined CED consumption and predictors of CED use over time in a large sample of Canadian secondary school students participating in the COMPASS study.

Using linked longitudinal data (n = 4949) from the first three years of the COMPASS study (2012/13 to 2014/15), three logistic Generalized Estimated Equation models were performed to examine predictors of weekday CED use, weekend CED use, and weekly CED use.

The prevalence of weekly CED use remained fairly consistent across the three years of follow-up; 12.5% in year-1, 11.3% in year-2, and 11.4% in year-3. Smokers and marijuana users at follow-up were all at greater odds of weekday or weekly CED use, regardless of baseline use. Binge drinkers at baseline were at greater odds for weekday or weekly CED use, but not if they started binge drinking after their baseline year. Marijuana users at follow-up were all at greater odds of weekend CED use, regardless of baseline marijuana use.

> 1 in 10 youth reported consuming CEDs one or more times per week, where specific subpopulations of youth, such as marijuana users, appear to be more frequent CED users. Although CED use remained relatively constant over the three-year period examined, prevalence of CED use remains problematic among secondary school students.

1. Background

Caffeinated energy drinks (CEDs) commonly contain a moderate to high level of caffeine, stimulating herbal supplements, and sugar or sugar derivatives (McCusker et al., 2006; Health Canada, 2015a). Evidence suggests that within the CED market, nearly half of consumers are 25 years of age or younger (Pomeranz et al., 2013; Babu et al., 2008; Clauson et al., 2008). While Health Canada recommends limiting daily caffeine intake among adolescents to ≤ 2.5 mg/kg body weight, it has been reported that the typical CED available in the Canadian market contains between 80 and 180 mg of caffeine (Health Canada, 2013; Health Canada, 2015b). Therefore, in accordance with the WHO growth charts for Canada (Dieticians of Canada, 2014a), an 18 year old male in the 50th percentile for body weight (66 kg) would exceed his recommended daily limit of caffeine from consuming just one CED containing 165 mg of caffeine, or more.

In addition to the health risks of consuming sugar-sweetened beverages (e.g., obesity, diabetes and cardiovascular disease) (Malik et al., 2010), excessive caffeine consumption can result in vomiting, insomnia and sleep disturbances, tachycardia, serious cardiovascular and neurological events (Ali et al., 2015; Wolk et al., 2012). Beyond these known negative side effects, documented hospitalizations and high-profile deaths as a direct result from consuming CEDs have been reported in both Canada and the United States (Bailey, 2012; Informer C, 2018) and as such, consumption of these products by youth should be considered as problematic (Seifert et al., 2011). In Canada, there are currently no regulatory measures to restrict youth access to, or consumption of CEDs (Health Canada, 2015c; Health Canada, 2012), which may contribute to their widespread use. CEDs are often permitted for sale within school environments across Canada, however, the School Food and Beverage Policy (PPM 150) implemented in 2010 (Ontario Ministry of Education, 2010) prohibits the sale of CEDs within publicly funded schools in Ontario. Despite this, consumption of CEDs by youth in Ontario remains high: 49.6% of grade 7 to grade 12 students in 2011 reported past year CED use and 19.1% reported CED use in the previous week (Hamilton et al., n.d.). A more recent study conducted in 2017, identified that within a small sample of Canadian youth and young adults, 73.6% of respondents reported ever consuming CEDs and 12.6%

reported consuming > 50 CEDs in their lifetime (Reid et al., 2017). Given the lack of regulations pertaining to the ingredients, labelling, and marketing of CEDs (Health Canada, 2012), coupled with the high frequency and volume of CED use reported by Canadian youth (Hamilton et al., n.d.; Reid et al., 2015; Azagba et al., 2014), there is a need to better understand youth consumption patterns to inform future prevention actions (MacDonald et al., 2010; Arria et al., 2014).

Available cross-sectional evidence suggests that youth are more likely to consume CEDs if they are male, older, or use other substances such as tobacco, marijuana or alcohol (Reid et al., 2015; Azagba et al., 2014). Additionally, longitudinal evidence has found consuming energy drinks predicted subsequent alcohol use among youth (Miyake and Marmorstein, 2015). Robust literature has identified a strong association between CEDs and high-risk alcohol consumption (Marczinski and Fillmore, 2014), and has noted significant associations with alcohol dependence and related consequences (Skewes et al., 2013). Research also suggests that consumption of CEDs commonly occurs before or after school hours and on non-school days (Calamaro et al., 2009; Bryant Ludden and Wolfson, 2010), although there is some evidence to indicate that CEDs are consumed at school (Reid et al., 2017). Most existing research that has examined the negative consequences of consuming CEDs has been cross-sectional, leading to a paucity of knowledge pertaining to the long-term and causal health effects of youth CED use (Health Canada, 2012). Current literature suggests CEDs are strongly associated with substance use behaviours (Reid et al., 2015; Azagba et al., 2014) and as such, there is a need for additional longitudinal research to better understand how health behavioural patterns cluster to inform prevention, intervention and policy (Arria et al., 2014).

To the best of our knowledge, there have been no longitudinal examinations of CED use among Canadian youth. As such, this study seeks to explore changes in weekday and weekend CED use over time using data from COMPASS, a cohort study collecting health behaviour data from a large sample of Canadian youth. Specifically, we aim to examine how binge drinking, marijuana use, and cigarette smoking are related to CED use over time. We hypothesize that any substance use, particularly early onset, will be associated with more weekday and weekend CED use.

2. Methods

2.1. Design

COMPASS a prospective cohort study designed to collect longitudinal data from a large sample of grade 9 to 12 secondary school students (ages 14 to 19 years of age) and the schools they attend in Ontario, Canada (Leatherdale et al., 2014). The current study reports longitudinal student-level linked data from Year 1 (Y_1: 2012–2013), Year 2 (Y_2: 2013–2014), and Year 3 (Y_3: 2014–2015). The COMPASS student questionnaire (Cq) was used to collect self-reported behavioural and correlate data from whole school samples during class time. A full description of the COMPASS host study methods is available in print (Leatherdale et al., 2014) or online (www.compass.uwaterloo.ca). COMPASS received ethics approval from the University of Waterloo Human Research Ethics Committee and all participating school boards (ORE #: 17264).

2.2. Participants

In Y_1, 43 schools in Ontario were purposefully recruited using an active-information passive-consent permission protocol (Leatherdale et al., 2014). Passive consent reduces the effects of systematic sample bias and has been identified as an important recruitment protocol for collecting robust data on youth substance use behaviours (Rojas et al., 2008). Students could decline to participate at any time. In Y_1, data were collected from 24,173 grade 9 to 12 students (80.2% participation

rate) in 43 schools. Our Y_2, data were collected from 23,424 grade 9 to 12 students (78.2% participation rate) in the same 43 schools, and an additional 46 schools were recruited into the study where data were also collected from 27,284 grade 9 to 12 students (80.2% participation rate). Our Y_3 data were collected from 42,355 grade 9 to 12 students (78.7% participation rate) in 87 schools (2 schools of the original 43 Y_1 schools dropped out between Y_2 and Y_3). Missing respondents resulted primarily from scheduled free periods where they are not expected to be in a class or absenteeism during data collection.

In order to explore longitudinal changes among respondents, we linked Y_1, Y_2, and Y_3 student-level data within schools using a unique code generated by each student. The process of linking the student data across waves is described in more detail by Qian and colleagues (Qian et al., 2015a). Due to the rolling sample design of COMPASS, it was not possible to link three years of data with the grade 11 or 12 students in Y_1 that would have graduated and not attended the school in Y_3, or the grade 9 students newly admitted to participating schools in Y_2 or Y_3. Other reasons for non-linkage included students transferring schools, students on a free period/absent on the time of a data collection in their school, or students dropping out of school. Overall, 27,329 students were successfully linked for at least two years of the study (Y_1-Y_2, Y_2-Y_3, Y_1-Y_3, or Y_1-Y_2-Y_3), with 39.6% (n = 4767) of the original Y_1 sample of grade 9 and 10 students (n = 12,046) completing the questionnaire in all three years. Of the participating students in Y1-Y3, 4960 were linked for three years of participation. Additionally, 11 students were removed from analysis due to missing data on covariates, resulting in a final sample of 4949 students that were included within our analysis. Missing data was treated as missing completely at random and excluded on an analysis-by-analysis basis for each model performed. Previous research (Qian et al., 2015b) using the linked COMPASS data are available to highlight potential differences between the linked and non-linked longitudinal samples.

2.3. Measures

2.3.1. Caffeinated energy drink (CED) use

Consistent with previous research (Reid et al., 2015), respondents were asked to report "In a usual school week (Monday to Friday), on how many days do you drink high-energy drinks (Redbull, Monster, Rock Star, etc.)?", and "On a usual weekend (Saturday and Sunday), on how many days do you drink high-energy drinks (Redbull, Monster, Rock Star, etc.)?". Given the positively skewed distribution of responses to both measures, we opted to derive three binary outcomes using the response to these two questions. Those who reported usually consuming a CED on one or more days during the school week were considered *Weekday CED users (Yes* vs. *No)*. Those who reported usually consuming a CED on one or two days during the weekend were considered *Weekend CED users (Yes* vs. *No)*. Those who reported consuming a CED on one or more days during the school week or on the weekend were considered *Weekly CED users (Yes* vs. *No)*.

2.3.2. Substance use

The substance use items in the Cq were based on measures used in national surveys of youth substance use (Elton-Marshall et al., 2011) and common definitions used to define use patterns (i.e., use in the past 30 days) among youth populations (Reid et al., 2015; Azagba et al., 2014; Qian et al., 2015b; Elton-Marshall et al., 2011; Patte et al., 2016a; Patte et al., 2016b). Respondents were asked to report, "In the last 12 months, how often did you have five or more drinks of alcohol on one occasion?". Those who responded binge drinking one or more times in the past month were considered as binge drinkers. While the available Cq measure for binge drinking does not align with the low-risk drinking guideline for binge drinking among females (four or more drinks on one occasion), (National Alcohol Strategy Advisory Committee, 2014) the questionnaire measure is consistent with national youth surveillance measures (Elton-Marshall et al., 2011) hence the results we present are

a conservative estimate of the potential impact of binge drinking among females. Respondents were asked to report, "In the last 12 months, how often did you use marijuana or cannabis? (a joint, pot, weed, hash)?". Those who reported using marijuana one or more times in the past month were considered as marijuana users. Respondents were asked to report, "On how many of the last 30 days did you smoke one or more cigarettes?". Those who reported any smoking in the last 30 days were considered as smokers.

2.3.3. Correlates

Consistent with previous research (Patte et al., 2016a; Patte et al., 2016b); demographic variables that were included within analysis were as follows: self-reported gender (male, female), grade (Malik et al., 2010; Ali et al., 2015; Wolk et al., 2012; Bailey, 2012), and race/ethnicity (White, Black, Asian, Hispanic, Off-Reserve Aboriginal, and other/mixed/missing). Age was not included due to the high correlation with grade, which is a more meaningful indicator for school-based prevention planning.

2.4. Analyses

Only those students with complete responses for outcome, predictors and covariate variables for all three years examined were used in these models. Frequency statistics of the sample were calculated. Frequency of weekly, weekday and weekend CED use was also explored. Chi-square analyses were conducted to compare differences between males and females (at baseline).

Student responses were examined for how maintaining substance use behaviours at baseline or initiating substance use behaviour after baseline was related to CED consumption. Applying binge drinking, marijuana use and cigarette use as our main predictors, three separate logistic Generalized Estimating Equations (GEE) models were constructed for our binary outcomes of Weekday CED use (Model 1), Weekend CED use (Model 2), and Weekly CED use (Model 3). Predictors were used at baseline and follow-up (baseline adjusted predictors), to evaluate the longitudinal effect of predictors and reduce confounding of cross-sectional effects. A single predictor variable was created to assess the presence of substance use at Y_2 or Y_3. To decompose the longitudinal effects and cross-sectional effects, research (Fitzmaurice and Laird, 2010) suggest to include predictors adjusted to individual mean or, individual baseline plus mean and baseline. That is, where the coefficient of mean or baseline represents the cross-sectional effects, and coefficients of adjusted predictors represents the longitudinal effects. The odds ratio indicates the change in the odds of CED use, corresponding to a single measure of behaviour change in substance use at follow-up. If the baseline value was missing, then participant data was not included within the complete-case analysis. All regression models were adjusted for gender, grade, ethnicity and school ID to account for school clustering. The within-school and within-individual associations were considered by specifying pairwise odds ratio in the model. Computation was completed is SAS 9.4 and modeling was implemented using the procedures PROC GENMOD.

3. Results

The prevalence of weekly CED use remained fairly consistent across the three years of follow-up, where 12.5% (n = 606 of 4867 students) were weekly users in Y_1, 11.3% (n = 544 of 4877 students) were weekly users in Y_2, and 11.4% (n = 545 of 4842 students) were weekly users in Y_3. Descriptive statistics of the baseline year for CED use and covariate measures are reported in Table 1 by gender. Compared to females, males more commonly reported weekday, weekend and weekly use of CEDs. Moreover, among students who reported using CEDs, nearly one in three had indicated consuming CEDs on weekdays. Fig. 1 shows the frequency of weekday and weekend CED use at baseline year by gender.

Table 1
Baseline characteristics of the linked longitudinal sample of COMPASS students by gender (Ontario, Canada).

Covariates	Total n = 4949	Female n = 2708	Male n = 2241	P-value
	% (n)[a]	% (n)[a]	% (n)[a]	
Weekday CED use				
No	89.6 (4375)	92.6 (2480)	85.8 (1895)	df = 1,
Yes	10.4 (510)	7.4 (197)	14.2 (313)	< 0.0001
Weekend CED use				
No	92.6 (4529)	95.0 (2541)	89.8 (1988)	df = 1,
Yes	7.4 (360)	5.0 (135)	10.2 (225)	< 0.0001
Weekly CED use				
No	87.5 (4261)	91.0 (2425)	83.3 (1836)	df = 1,
Yes	12.5 (606)	9.0 (239)	16.7 (367)	< 0.0001
CED use				
Both weekday and weekend	5.4 (264)	3.5 (93)	7.8 (171)	df = 1,
Weekday use only	4.9 (236)	3.8 (100)	6.2 (136)	< 0.0001
Weekend use only	1.8 (88)	1.5 (40)	2.2 (48)	
No	87.9 (4261)	91.2 (2425)	83.8 (1836)	
Binge drinking				
Yes	9.9 (492)	9.8 (266)	10.1 (226)	df = 1,
No	90.1 (4457)	90.2 (2442)	89.9 (2015)	0.7591
Marijuana use				
Yes	5.9 (290)	5.0 (135)	6.9 (155)	df = 1,
No	94.1 (4659)	95.0 (2573)	93.1 (2086)	0.004
Cigarette use				
Yes	1.0 (48)	0.7 (20)	1.2 (28)	df = 1,
No	99.0 (4901)	99.3 (2688)	98.8 (2213)	0.0679
Grade				
9	54.4 (2693)	55.4 (1500)	53.2 (1193)	df = 3,
10	41.7 (2064)	41.9 (1136)	41.4 (928)	< 0.0001
11	3.8 (186)	2.6 (70)	5.2 (116)	
12	0.1 (6)	0.1 (2)	0.2 (4)	
Ethnicity				
White	76.3 (3775)	76.6 (2074)	75.9 (1701)	df = 5,
Black	3.5 (171)	3.1 (84)	3.9 (87)	0.7367
Asian	6.6 (329)	6.5 (176)	6.8 (153)	
Aboriginal (First Nations, Métis, Inuit)	1.7 (82)	1.6 (44)	1.7 (38)	
Latin American/ Hispanic	2.1 (106)	2.2 (60)	2.1 (46)	
Other/mixed/missing	9.8 (486)	10.0 (270)	9.6 (216)	

[a] Note: The numbers may not be added up to the total due to missing values and rounding. In the baseline year, 31 females and 33 males were missing their weekday consumption value and 32 females and 28 males were missing their weekend consumption value.

The results of the three logistic GEE models for the Y_3 linked sample are shown in Table 2. Longitudinal analysis of this cohort shows use of CEDs is relatively fixed over a recent three year period of time. CED use was stable among students who were substance users at baseline. Youth who were users of other substances had greater risk of CED consumption; as shown in Model 1 (N = 4749), smokers and marijuana users at follow-up were all at greater odds of weekday CED use, regardless of whether or not they were smoking or using marijuana during their first year of participating in the study (baseline). Binge drinkers at baseline were at greater odds for weekday CED use, but not if they started binge drinking after their baseline year. As shown in Model 2 (N = 4772), marijuana users were all at greater odds of weekend CED use, regardless of whether or not they were using marijuana during baseline. As shown in Model 3 (N = 4701), smokers and marijuana users at follow-up were all at greater odds of weekly CED use, regardless of whether or not they were smoking or using marijuana during their baseline year. Binge drinkers at baseline were at greater odds for weekly CED use, unless binge drinking occurred after their baseline year (follow-up). Students who reported using marijuana products during their first year of participating in the study were at an increased risk for CED use for all three outcomes.
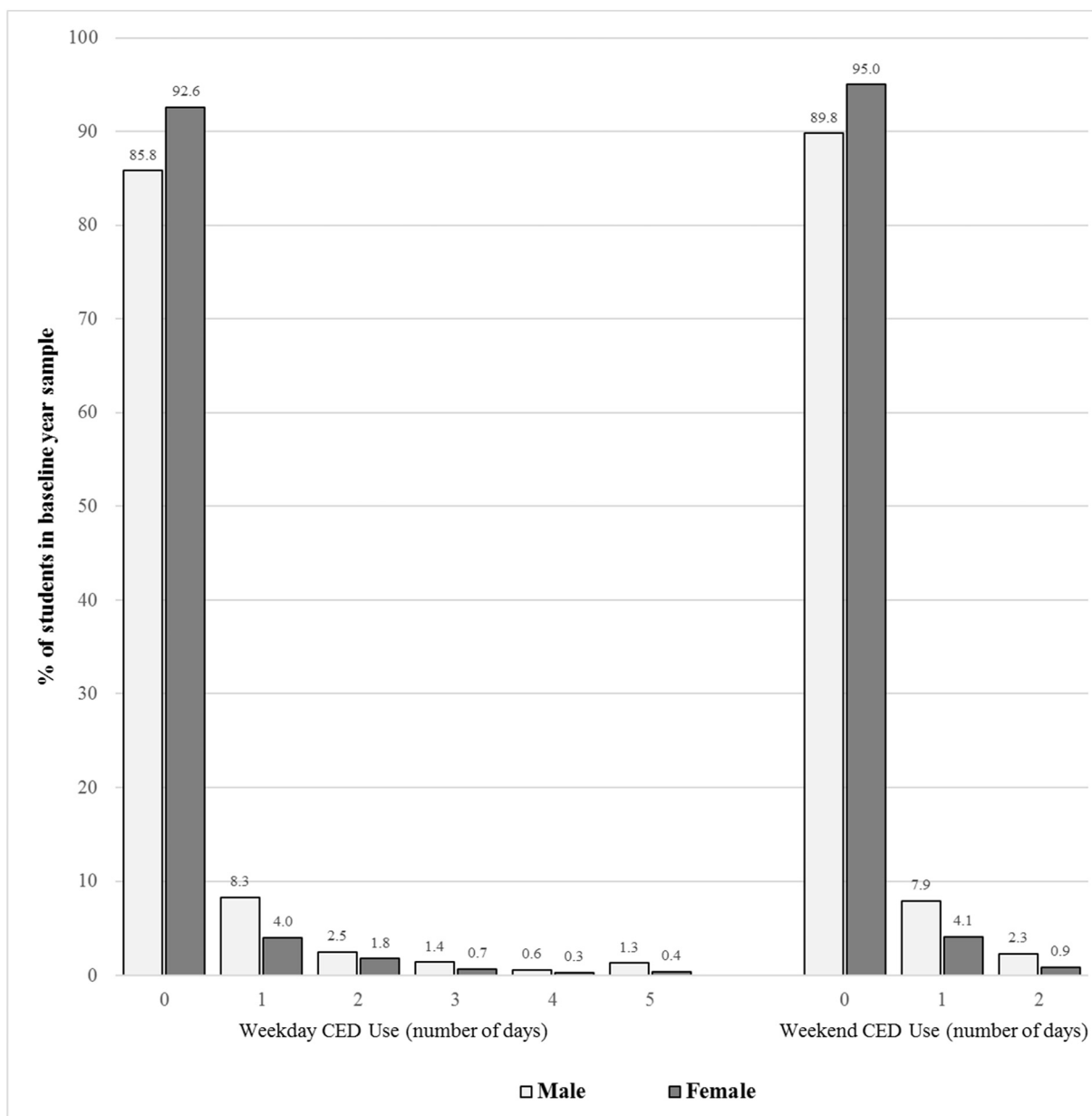
Fig. 1. Frequency of weekday and weekend CED use among Ontario students participating in the COMPASS Study (2012–2015)
This figure demonstrates the baseline frequency of weekday and weekend caffeinated energy drink (CED) use among respondents in the linked longitudinal sample (Years 1 to 3) of the COMPASS study by gender (Ontario, Canada).

4. Discussion

This study highlights that > 1 in 10 youth participating in this study reported consuming CEDs one or more times per week. In accordance with previous research, we found that CEDs were more frequently consumed among specific subpopulations including males (Reid et al., 2015; Azagba et al., 2014), and youth using marijuana or tobacco products (Hamilton et al., n.d.; Azagba et al., 2014). Given the concerns raised at Health Canada and in the medical community about the potential harms of excessive caffeine consumption among youth (Health Canada, 2012; MacDonald et al., 2010), the evidence presented here suggests that CED use among youth warrants additional attention within the Canadian context. Our findings are comparable to CED use patterns within a large U.S. sample of youth (Monitoring the Future), whereby prevalence of weekly use of CEDs was high and more common among young males and marijuana users (Arria et al., 2014; Terry-McElrath et al., n.d.). Prevalence of use remains stable and problematic

among particular groups of secondary school students who are already at-risk given their co-occurring substance use behaviours.

Consistent with other research, youth who were users of other substances (e.g. tobacco and marijuana) (Hamilton et al., n.d.; Azagba et al., 2014; Miyake and Marmorstein, 2015; Terry-McElrath et al., n.d.) had a higher risk of CED use. Specifically, we found that the time of substance use onset was an important indicator of CED consumption, and students that reported tobacco or marijuana use during their first year (baseline) participating in the COMPASS study were at a substantially higher risk of weekday and weekend CED use compared to those who engaged in these behaviours after the baseline year. While previous research is limited to cross-sectional evidence and reverse causality of associations are possible, our findings suggest this is unlikely. Moreover, this study builds off existing evidence identifying a significant association between CED use and sensation seeking (Arria et al., 2011; Evren and Evren, 2015), and demonstrates a clustering of health behaviours (i.e. sensation seeking youth are more commonly

Table 2
Logistic GEE models examining the within-individual association of reported substance use at follow-up with CED use among participating COMPASS students in 2012–2015 (Ontario, Canada).

	OR	95% CI		Pr (> |Z|)
		Lower	Upper	
Model 1: weekday CED use: Yes vs No				
(N = 4749)				
Binge drinking				
Baseline	1.44	1.29	1.61	< 0.0001
Using at follow-up	1.02	0.93	1.13	0.6364
Marijuana use				
Baseline	2.66	2.10	3.36	< 0.0001
Using at follow-up	2.11	1.73	2.57	< 0.0001
Cigarette use				
Baseline	7.29	4.99	10.63	< 0.0001
Using at follow-up	2.26	1.58	3.23	< 0.0001
Model 2: weekend CED use: Yes vs. No				
(N = 4772)				
Binge drinking				
Baseline	1.35	1.16	1.58	0.0001
Using at follow-up	0.94	0.81	1.09	0.4164
Marijuana use				
Baseline	3.49	2.47	4.92	< 0.0001
Using at follow-up	2.27	1.72	3.00	< 0.0001
Cigarette use				
Baseline	3.21	1.77	5.81	0.0001
Using at follow-up	1.75	1.08	2.82	0.0223
Model 3: weekly CED use: Yes vs. No				
(N = 4701)				
Binge drinking				
Baseline	1.40	1.25	1.57	< 0.0001
Using at follow-up	0.98	0.90	1.08	0.6917
Marijuana use				
Baseline	3.10	2.52	3.80	< 0.0001
Using at follow-up	2.14	1.76	2.60	< 0.0001
Cigarette use				
Baseline	5.58	3.78	8.25	< 0.0001
Using at follow-up	1.96	1.34	2.85	0.0005

Note: Models are adjusted for ethnicity, grade and gender. The sample used only includes those students with complete information of outcome and covariates/predictors for Y1 – Y3.
Pr (> \|Z\|): z score probability.
Baseline: response [Yes (1) vs. No (0)] for the baseline year among early onset users (i.e., already using in Year 1).
Using at follow-up: the difference between repeated measurements and the baseline data among late onset users. These are students who reported substance use after the baseline year (i.e., not using at baseline but started using in either Year 2 or Year 3).

substance users and CED consumers) that may be valuable to consider for future research. Considering the known harms associated with youth consumption of CED(Ali et al., 2015; Wolk et al., 2012; Health Canada, 2015c; Health Canada, 2012; Dieticians of Canada, 2014b), these findings suggest prevention of CED among youth warrants public health attention and more adequate regulations.

Many cross-sectional studies have noted a strong association between CED intake and alcohol consumption among youth (Reid et al., 2015; Azagba et al., 2014; Terry-McElrath et al., n.d.). For instance, Reid and colleagues (Reid et al., 2015) identified that COMPASS participants in year 1 who reported consuming any level of alcohol were more likely to use CEDs, and the odds of CED use increased positively with frequency of alcohol intake. However, our longitudinal analyses with the COMPASS data identified that tobacco and marijuana use were greater predictors of CED intake over time, and alcohol use was insignificantly related to CED consumption (especially late onset alcohol use) when controlling for smoking and marijuana use. These conflicting observations emphasize the importance of longitudinal data and

highlight the need for ongoing research in this domain. It would be beneficial to use future waves of the longitudinal COMPASS data to determine the temporal sequence of the onset of these substances. Considering more youth in our sample at baseline reported using CEDs than alcohol, marijuana or tobacco, it is important to explore if CED use is actually a potential gateway product to other substance use, as has been previously suggested as a priority domain for future research (Reissig et al., 2009). Moreover, it would also be beneficial to use the built environment data available in the COMPASS system to explore how contextual characteristics surrounding youth, such as the location and density of retailers that sell CEDs, impact the use and frequency of use of CEDs.

We identified that a considerable proportion of youth reported distinct CED consumption patterns over the span of a usual week. Although previous research suggests that CEDs are generally consumed by adolescents on non-school days, outside of school hours and at home (Bryant Ludden and Wolfson, 2010; Nowak and Jasionowski, 2015), our finding of predominate week day use of CEDs is novel and also consistent with previously observed behaviour patterns in research exploring youth tobacco use (Nowak and Jasionowski, 2015). However, these findings should be interpreted with caution whereby consumption of CED may be higher during weekend days when mixed with alcohol (AmED). As well, different CED consumption patterns over a usual week were associated with substance use. Results show that marijuana users were at a slightly increased risk of consuming CEDs on weekends and students who were tobacco smokers reported significantly higher weekday intake of CEDs. Prevalent weekday CED consumption, as well as its correlation with substance use, provides important justification for school-based prevention efforts targeted to youth CED consumption.

4.1. Prevention implications

Considering the effectiveness of previous school-based intervention approaches (e.g. prohibiting smoking on school property), our findings suggest that preventing the possession of CEDs among youth while at school may be an important initial step for prevention efforts (Health Canada M of S and SC, 2002; Moore et al., 2001). As CED consumption is observed more frequently in students who report early onset substance use, it may be beneficial to target youth as early as elementary school, before onset occurs, to provide them with necessary education and knowledge about these health hazards. Employing a school-based policy that restricts the use of CEDs on school property, may have a positive effect in reducing the consumption in weekday only users and could also limit overall youth intake of CEDs. Consistent implementation and comprehension of school policies by students, as well as the advisors who enforce policy within schools, is critical for effective implementation and adherence (Vine et al., 2017; Visram et al., 2017).

4.2. Future research

Considering COMPASS does not collect data on student attitudes towards CEDs, motives for consumption (e.g. social pressures), or whether these beverages are consumed during school hours specifically and why (i.e. reduced parental monitoring), it would be important for future research to examine the relationship between youth perceptions of CEDs and motives for consumption to understand the effectiveness of a school-based CED control policy. Going forward, research and intervention strategies may benefit from considering the clustering of health behaviours, as demonstrated in this study, when targeting high-risk students. Moreover, future research should examine if predictors and consumption patterns found to be significantly related to CED consumption over time in this study, are similar for students reporting use of AmEDs.

4.3. Limitations

A number of limitations merit discussion. While reverse causation cannot be ruled out, the longitudinal design and the statistical modeling procedures used make this unlikely. Likewise, confounding can never been fully discounted in observational research. Data were unavailable on some potential confounders (e.g., socioeconomic status, parental education or occupation, student mental health) and as such limits the controls that could be included within analysis. Self-report questionnaires are subject to recall bias and underreporting, and linkage rates tend to be lower for students who use alcohol or marijuana (Qian et al., 2015b), however, a recent meta-analysis (Rojas et al., 2008) provided support for the benefits of using active-information with passive consent procedures (as was used in COMPASS) to reduce systematic sample bias that is common in youth substance use surveys using active consent methods.

As this study uses a complete-case analysis, these findings could under or over-estimate the relationships identified as a result of selection bias, given that unreported (due to discomfort in reporting on substance use) or missing (due to truancy or absenteeism) data is typically more common among students who use substances. The available COMPASS measures for CED consumption does not specify that high-energy drinks refers to caffeine containing beverages. While examples of beverages are provided within the item (e.g., Red Bull, Monster, Rock Star, etc.) there is possibility for students to misclassify sports drinks or other beverages for caffeine containing leading to an over- or underestimation of CED consumption. Moreover, these measures only allow us to examine the numbers of days a respondent consumed CEDs, not the total number of CEDs. As such, our estimates of CED use among youth presented here are conservative due to the unit of measure used (i.e., number of days participants consumed CEDs as compared to volume or number of CEDs).

5. Conclusion

While CED consumption remains generally constant over the three-year period examined (2012–2015), the prevalence of CED use continues to be problematic among secondary school students where > 1 in 10 youth reported consuming CEDs at least weekly. Additionally, our results demonstrate specific subpopulations of youth, such as marijuana users, appear to be more frequent CED users. Despite the limitations discussed, this analysis has highlighted the need for researchers and stakeholders to consider youth CED consumption more closely as a modifiable risk factor among youth populations moving forward. CED use is common among youth in this study, yet unlike the other substances examined here (i.e., alcohol, tobacco, marijuana) that are highly regulated to prevent youth use and access; CEDs are not as regulated and are widely available and marketed to youth populations.

Abbreviations

CED   caffeinated energy drink
GEE   Generalized Estimated Equation
AmED   Alcohol mixed Energy Drink

Ethics approval and consent to participate

The COMPASS Study received ethics approval from the University of Waterloo Office of Research Ethics as well as participating school boards (ORE#: 30118). Using an active-information, passive-consent protocol, all participants gave consent for the use of their anonymous data.

Consent for publication

Ethics approval and consent to participate

Availability of data and material

A data request form to access to the COMPASS data can be found at: https://uwaterloo.ca/compass-system/information-researchers/data-usage-application.

Authors' contributions

AEB conceived the manuscript idea, drafted the manuscript and revised the manuscript for content. WQ performed the statistical analyses, drafted the results, and revised the manuscript for content. STL conceived the host study, led the acquisition of all data, drafted components of introduction and discussion, and revised the manuscript for critical content. All authors that have contributed significantly to the work presented within this manuscript have been listed above. All authors have read and approved the final manuscript.

Declaration of Competing Interest

The authors declared they have no competing interests.

References

Ali, F., Rehman, H., Babayan, Z., Stapleton, D., Joshi, D.-D., 2015. Energy drinks and their adverse health effects: a systematic review of the current evidence. Postgrad Med [Internet] 127 (3), 308–322. Apr [cited 2015 Dec 1]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25560302.

Arria, A.M., Caldeira, K.M., Kasperski, S.J., Vincent, K.B., Griffiths, R.R., O'Grady, K.E., 2011. Energy drink consumption and increased risk for alcohol dependence. Alcohol. Clin. Exp. Res. 35 (2), 365–375.

Arria, A.M., Bugbee, B.A., Caldeira, K.M., Vincent, K.B., 2014. Evidence and knowledge gaps for the association between energy drink use and high-risk behaviors among adolescents and young adults. Nutr Rev [Internet] 72 (Suppl. 1), 87–97. Oct [cited 2015 Dec 1]. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4196711&tool=pmcentrez&rendertype=abstract.

Azagba, S., Langille, D., Asbridge, M., 2014 May. An emerging adolescent health risk: caffeinated energy drink consumption patterns among high school students. Prev Med (Baltim) 62, 54–59. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24502849.

Babu, K.M., Church, R.J., Lewander, W., 2008. Energy drinks: the new eye-opener for adolescents. Clin Pediatr Emerg Med.

Bailey, A., 2012. Energy drinks suspected to have caused of 3 Canadians. In: The Toronto Star [Internet], Available from: http://www.thestar.com/news/canada/2012/11/18/energy_drinks_suspected_to_have_caused_deaths_of_3_canadians.html.

Bryant Ludden, A., Wolfson, A.R., 2010. Understanding adolescent caffeine use: connecting use patterns with expectancies, reasons, and sleep. Health Educ. Behav. 37 (3), 330–342. [Internet]. Jun [cited 2015 Dec 1]. Available from. http://www.ncbi.nlm.nih.gov/pubmed/19858312.

Calamaro, C.J., Mason, T.B.A., Ratcliffe, S.J., 2009. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. Pediatrics [Internet] 123 (6), e1005–e1010. Jun [cited 2015 Sep 6]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19482732.

Clauson, K.A., Shields, K.M., McQueen, C.E., Persad, N., 2008. Safety issues associated with commercially available energy drinks. J Am Pharm Assoc JAPhA 48 (3), e55–e67.

Dieticians of Canada, 2014a. WHO Growth Charts for Canada: Boys [Internet]. Available from: https://www.dietitians.ca/Downloads/Public/HFA-WFA_2-19_BOYS_EN.aspx.

Dieticians of Canada, 2014b. WHO Growth Charts for Canada: Boys.

Elton-Marshall, T., Leatherdale, S.T., Manske, S.R., Wong, K., Ahmed, R., Burkhalter, R., 2011. Research methods of the youth smoking survey (YSS). Chronic Dis Inj Can 32

(1), 47–54.

Evren, C., Evren, B., 2015. Energy-drink consumption and its relationship with substance use and sensation seeking among 10th grade students in Istanbul. Asian J. Psychiatr. 15, 44–50. [Internet]. Jun [cited 2015 Dec 1]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26006774.

Garrett M. Fitzmaurice, Nan M. Laird JHW. Applied Longitudinal Analysis. New Jersey: John Wiley& Sons Inc; 2010. (215 p).

Hamilton HA, Boak A, Ilie G, Mann RE. Energy drink consumption and associations with demographic characteristics, drug use and injury among adolescents. Can J Public Health [Internet]. Jan [cited 2015 Dec 1];104(7):e496–501. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24495828

Health Canada, 2012. Health Canada's Proposed Approach to Managing Caffeinated Energy Drinks. [Internet]. Available from: https://www.canada.ca/en/health-canada/services/food-nutrition/legislation-guidelines/policies/proposed-approach-managing-caffeinated-energy-drinks-2011-consultation-document.html.

Health Canada, 2013. Health Canada Reminds Canadians to Manage their Caffeine Consumption [Internet]. Available from: http://healthycanadians.gc.ca/recall-alert-rappel-avis/hc-sc/2013/34021a-eng.php.

Health Canada, 2015a. Caffeinated Energy Drinks.

Health Canada, 2015b. Category specific guidance for temporary marketing authorization - caffeinated energy drinks [Internet]. Available from: http://www.hc-sc.gc.ca/fn-an/legislation/guide-ld/guidance-caf-drink-boiss-tma-amt-eng.php.

Health Canada, 2015c. Category specific guidance for temporary marketing authorization - caffeinated energy drinks [Internet]. Available from: https://www.canada.ca/en/health-canada/services/food-nutrition/legislation-guidelines/guidance-documents/category-specific-guidance-temporary-marketing-authorization-caffeinated-energy-drinks.html.

Health Canada M of S and SC, 2002. 2002 Youth Smoking Survey: Technical Report. [Internet]. Available from: http://www.hc-sc.gc.ca/hl-vs/pubs/tobac-tabac/yss-etj-2002/index_e.html.

Informer C, 2018. Documented Deaths by Caffeine. Available from: https://www.caffeineinformer.com/a-real-life-death-by-caffeine.

Leatherdale, S.T., Brown, K.S., Carson, V., Childs, R.A., Dubin, J.A., Elliott, S.J., et al., 2014. The COMPASS study: a longitudinal hierarchical research platform for evaluating natural experiments related to changes in school-level programs, policies and built environment resources. BMC Public Health 14, 331. https://doi.org/10.1186/1471-2458-14-331. [Published 2014 Apr 8].

MacDonald, N., Stanbrook, M., Hébert, P.C., 2010. "Caffeinating" children and youth. CMAJ 182 (15), 1597. https://doi.org/10.1503/cmaj.100953.

Malik, V.S., Popkin, B.M., Bray, G.A., Després, J.P., Hu, F.B., 2010. Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. Circulation 121 (11), 1356–1364. https://doi.org/10.1161/CIRCULATIONAHA.109.876185.

Marczinski, C.A., Fillmore, M.T., 2014. Energy drinks mixed with alcohol: what are the risks? Nutr. Rev. 72 Suppl 1 (1), 98–107. https://doi.org/10.1111/nure.12127.

McCusker, R.R., Goldberger, B.A., Cone, E.J., 2006. Caffeine content of energy drinks, carbonated sodas, and other beverages. J. Anal. Toxicol. 30 (2), 112–114.

Miyake, E.R., Marmorstein, N.R., 2015. Energy drink consumption and later alcohol use among early adolescents. Addict. Behav. 43, 60–65. [Internet]. Apr [cited 2015 Dec 1]. Available from. http://www.ncbi.nlm.nih.gov/pubmed/25576951.

Moore, L., Roberts, C., Tudor-Smith, C., 2001. School smoking policies and smoking prevalence among adolescents: multilevel analysis of cross-sectional data from Wales. Tob. Control. 10 (2), 117–123. https://doi.org/10.1136/tc.10.2.117.

National Alcohol Strategy Advisory Committee. Low Risk Drinking Guide Summary: Youth and Alcohol [Internet]. Ottawa; 2014. Available from: http://www.ccsa.ca/Resource Library/CCSA-Youth-and-Alcohol-Summary-2014-en.pdf.

Nowak, D., Jasionowski, A., 2015. Analysis of the consumption of caffeinated energy drinks among polish adolescents. Int. J. Environ. Res. Public Health 12 (7), 7910–7921. Jul. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4515699&tool=pmcentrez&rendertype=abstract.

Ontario Ministry of Education, 2010. Policy/Program Memorandum No. 150 [Internet]. [cited 2018 Oct 4]. Available from: http://www.edu.gov.on.ca/extra/eng/ppm/150.html.

Patte, K.A., Laxer, R., Qian, W., Leatherdale, S.T., 2016a. Weight perception and weight-control intention among youth in the COMPASS study. Am. J. Health Behav. 40 (5), 614–623.

Patte, K.A., Laxer, R.E., Qian, W., Leatherdale, S.T., 2016b. An analysis of weight perception and physical activity and dietary behaviours among youth in the COMPASS study. SSM - Popul Heal 2, 841–849.

Pomeranz, J.L., Munsell, C.R., Harris, J.L., 2013. Energy drinks: an emerging public health hazard for youth. J. Public Health Policy 34 (2), 254–271.

Qian, W., Battista, K., Bredin, C., Brown, K.S.L.S., 2015a. Assessing Longitudinal Data Linkage Results in the COMPASS Study. Available from: https://uwaterloo.ca/compass-system/publications#technical.

Qian, W., Battista, K., Bredin, C., Brown, K.S.L.S., 2015b. Assessing Longitudinal Data Linkage Results in the COMPASS Study [Internet]. Waterloo, ON (4). Report No.: 3. Available from: https://uwaterloo.ca/compass-system/publications/assessing-longitudinal-data-linkage-results-compass-study.

Reid, J.L., Hammond, D., McCrory, C., Dubin, J.A., Leatherdale, S.T., 2015. Use of caffeinated energy drinks among secondary school students in Ontario: prevalence and correlates of using energy drinks and mixing with alcohol. Can J public Heal [Internet] 106 (3), e101–e108. Jan [cited 2015 Dec 1]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26125234.

Reid, J.L., McCrory, C., White, C.M., Martineau, C., Vanderkooy, P., Fenton, N., et al., 2017. Consumption of caffeinated energy drinks among youth and young adults in Canada. Prev Med Reports. 5, 65–70.

Reissig, C.J., Strain, E.C., Griffiths, R.R., 2009. Caffeinated energy drinks—a growing problem. Drug Alcohol Depend. 99 (1–3), 1–10. https://doi.org/10.1016/j.drugalcdep.2008.08.001.

Rojas, N.L., Sherrit, L., Harris, S., Knight, J.R., 2008. The role of parental consent in adolescent substance use research. J. Adolesc. Health 42 (2), 192–197. [Internet]. Available from. http://www.ncbi.nlm.nih.gov/pubmed/18207098.

Seifert, S.M., Schaechter, J.L., Hershorin, E.R., Lipshultz, S.E., 2011. Health effects of energy drinks on children, adolescents, and young adults. Pediatrics 127 (3), 511–528. https://doi.org/10.1542/peds.2009-3592. [published correction appears in Pediatrics. 2016 May;137(5):null].

Skewes, M.C., Decou, C.R., Gonzalez, V.M., 2013. Energy drink use, problem drinking and drinking motives in a diverse sample of Alaskan college students. Int J Circumpolar Health 72, 1–6.

Terry-McElrath YM, O'Malley PM, Johnston LD. Energy drinks, soft drinks, and substance use among United States secondary school students. J Addict Med [Internet]. Jan [cited 2015 Nov 13];8(1):6–13. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3910223&tool=pmcentrez&rendertype=abstract

Vine, M.M., Harrington, D.W., Butler, A., Patte, K., Godin, K., Leatherdale, S.T., 2017. Compliance with school nutrition policies in Ontario and Alberta: an assessment of secondary school vending machine data from the COMPASS study. Can J Public Heal 108 (1), 43–48.

Visram, S., Crossley, S.J., Cheetham, M., Lake, A., 2017. Children and young people's perceptions of energy drinks: a qualitative study. PLoS One 12 (11), e0188668 [Published 2017 Nov 30].

Wolk, B.J., Ganetsky, M., Babu, K.M., 2012. Toxicity of energy drinks. Curr. Opin. Pediatr. 24 (2), 243–251.