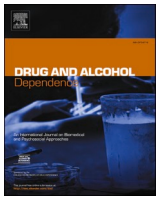
Drug and Alcohol Dependence 241 (2022) 109666

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep



Energy drinks and alcohol use among adolescents: A longitudinal study

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ARTICLE INFO

Keywords:
Adolescence
Energy drinks
Alcohol
Longitudinal

ABSTRACT

Background: Alcohol use is a leading cause of reduced health among young people. Consumption of energy drinks might be a risk factor for alcohol use. The aim of this study was to examine if more frequent consumption of energy drinks in early adolescence was associated with higher concurrent alcohol consumption, and with stronger increase in alcohol use throughout adolescence.

Methods: The data came from MyLife, a longitudinal study where Norwegian adolescents completed e-questionnaires in the autumn of 2017, 2018, 2019, 2020, and 2021. The participants were a nationwide sample of 2916 adolescents (mean age: 14.25 [SD = 0.85], 56% girls). At baseline, adolescents self-reported how often they had consumed energy drinks over the past month, a range of family factors, individual characteristics, and substance use. Self-reports of alcohol use (frequency, usual quantity, and frequency of consuming five or more units) were collected at all five assessments and combined into continuous variables.

Results: The results of fully adjusted growth curve models indicate that more frequent consumption of energy drinks at baseline was associated with greater concurrent alcohol use ($p < .001$), and greater increase in alcohol use over time ($p < .05$). The effect of energy drinks on concurrent alcohol use was stronger for girls, but the effect on increase over time was stronger for boys.

Conclusion: Consumption of energy drinks in early adolescence is associated with more alcohol use throughout adolescence, but the effect size was rather modest in this sample of Norwegian adolescents.

1. Introduction

Adolescent alcohol use, in particular episodic heavy drinking, is an important risk factor for reduced health among young people (Mokdad et al., 2016). It is also recognized as a risk factor for poor mental health and substance use disorders, as well as poor educational outcomes and labor market prospects in adulthood (Hill et al., 2000). Recent years have brought several changes in adolescent health behavior (Inchley et al., 2020; Pape et al., 2018), and updated knowledge about what constitutes important risk factors for new cohorts of adolescents is necessary if prevention strategies are to be effective (Hawkins et al., 1992; Toumbourou et al., 2019).

It has been suggested that consumption of energy drinks might be a risk factor for adolescent alcohol use (Dawodu and Cleaver, 2017; Marinoni et al., 2022). Energy drinks usually contain carbonated water, vitamins, carbohydrates, caffeine, taurine, and possibly other chemicals that serve to boost energy and mental performance (Aranda and Morlock, 2006). The consumption of energy drinks among adolescents has increased rapidly in recent years and has been characterized as a growing problem (Reissig et al., 2009). A study from Norway estimated that in 2019, 30% of adolescents consumed energy drinks at least once a week (Kaldenbach et al., 2021).

One theoretical explanation for a potential link between energy drinks and alcohol is that excessive consumption of caffeine and taurine can affect the reward system in the brain. This can result in altered sensitivity to alcohol, which in turn can increase the risk of harmful alcohol use (Hsu et al., 2009; Lubman et al., 2007; Yasuma et al., 2021). Similarly, it has been suggested that adolescents who have experience

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https://doi.org/10.1016/j.drugalcdep.2022.109666
Received 29 August 2022; Received in revised form 14 October 2022; Accepted 15 October 2022
Available online 19 October 2022

with one beverage that changes the way they feel, energy drinks in this case, may be more likely to consume another beverage that changes the way they feel (Marmorstein, 2019). A second explanation for the reported association between energy drinks and alcohol use is that mixing alcohol with energy drinks reduces the drowsing effect of alcohol and increases its reinforcing effect (Sweeney et al., 2017). Finally, a third theoretical explanation is that some adolescents have a common liability to involvement in several types of risky behavior such as delinquency and substance use (Jessor and Jessor, 1977; Vanyukov et al., 2012), and that energy drinks can be viewed as a new vice for susceptible adolescents. Importantly, this implies that the link between energy drinks and alcohol use can be explained by underlying factors such as personality, poor parenting, or peer influence.

Several cross-sectional studies have reported associations between consumption of energy drinks and alcohol use among adolescents (Dawodu and Cleaver, 2017; Marinoni et al., 2022). From cross-sectional studies it is unclear if energy drink consumption is prospectively associated with alcohol use, or if alcohol use increases the risk of consuming energy drinks. However, we have identified three studies with a prospective design. Barrense-Dias et al. (2016) assessed 621 adolescents initially aged 14 years on two occasions 2 years apart. Controlling for gender, age, sleep duration on schooldays, smoking, cannabis use and baseline alcohol use, they found that those who consumed energy drinks weekly at the first assessment were much more likely to engage in binge drinking at the second assessment than those who consumed energy drinks rarely or not at all. Choi et al. (2016) assessed 894 high school students twice 12 months apart. After controlling for gender, age, parental education, ethnicity, impulsivity, and baseline alcohol use, they found that energy drink consumption at the first assessment predicted alcohol drinking frequency at the second assessment, but the effect size was small, and consumption of energy drinks did not predict the usual quantity of alcohol drunk per occasion, or binge drinking. The third study assessed 144 adolescents initially aged 12 years on two occasions 16 months apart (Marmorstein, 2019; Miyake and Marmorstein, 2015). Controlling for gender, age, race, baseline alcohol use, peer alcohol use, alcohol expectancies, sensation-seeking and parental monitoring, greater energy drink consumption at the first assessment was associated with more regular alcohol use at the second assessment. The effect size was moderate to large.

These three previous prospective studies (Barrense-Dias et al., 2016; Choi et al., 2016; Marmorstein, 2019; Miyake and Marmorstein, 2015) yielded mixed results, leaving it unclear if energy drink consumption in adolescence should be considered an important risk factor for later alcohol use. There are also potentially important methodological limitations. These three studies all had only one follow-up assessment, which is a limitation because measurement of change over time with only two assessments can confound real change with measurement error (Rogosa et al., 1982). At least three assessments are preferred for estimating change over time (Singer and Willett, 2003). In addition, some potential confounders were not considered in these studies. Important risk factors for adolescent alcohol use might also be risk factors for consumption of energy drinks: additional potential confounders for the relationship between energy drinks and alcohol use include behavioral problems, symptoms of depression, amount of unstructured leisure time, and frequency of participation in sports practice (Brunborg et al., 2022; Dawodu and Cleaver, 2017; Marinoni et al., 2021, 2022). Lastly, alcohol use can be conceived as a continuum ranging from no drinking at all to daily drunkenness, with most adolescents at the lower end. For this reason, alcohol use should be analyzed as a continuum rather than as crude categories, especially when examining change over time (Van Walraven and Hart, 2008).

Against this backdrop, we used longitudinal data from a large sample of Norwegian adolescents who were assessed annually at five time points. We examined the longitudinal association between frequency of energy drink consumption at the beginning of the study and development in alcohol use over the next four years. To assess whether the putative association between energy drink consumption and alcohol use can be explained by potential confounders, we included a range of family factors, and individual characteristics (including substance use) in the analyses. In addition, we examined if the effect of energy drinks on the development of alcohol use was different for girls and boys.

2. Material and methods

2.1. Data source and sampling

This research is based on the MyLife study, which recruited a nationwide, geographically and socioeconomically heterogeneous sample of Norwegian adolescents from 33 middle schools in 2017. The recruitment and consent procedures and ethical approval are described in detail in the MyLife cohort profile (Brunborg et al., 2019). The MyLife project was approved by the Norwegian Data Protection Authority (reference no.: 15/01495) after ethical evaluation by the National Committee for Research Ethics in the Social Sciences and the Humanities (reference no.: 2016/137). Parental consent was required due to the participants' young age and was obtained for 3512 students. This group comprised a core sample that was invited to complete e-questionnaires at five assessments done annually in the autumn of 2017 (t1), 2018 (t2), 2019 (t3), 2020 (t4), and 2021 (t5).

The analysis was restricted to adolescents who participated at t1 and provided valid responses to the items about energy drinks. This analytical sample comprised 2916 adolescents (56% girls) with mean age 14.25 years (SD = 0.85; age range = 12.8–16.7) at t1. In follow-up assessments, the number of respondents (and % of t1 respondents) was 2473 (84.8%) at t2, 2278 (78.1%) at t3, 1995 (68.4%) at t4, and 1577 (54.1%) at t5. The fractions that participated at 1, 2, 3, 4 and 5 time points were 5%, 10%, 19%, 25% and 41% respectively. Three or more assessments were available for 84% of the analytical sample.

2.2. Measures

2.2.1. Outcome variable measured at t1 to t5

Alcohol use was measured with three questions similar to those that comprise the Alcohol Use Disorders Identification Test – Consumption (AUDIT-C) (Saunders et al., 1993). Participants indicated alcohol consumption frequency in the past 12 months, typical number of units of alcohol consumed per drinking occasion, and the frequency with which they had consumed 5 or more units of alcohol during a single day. The response options were recoded and summed according to the standard scoring for the AUDIT-C with scores ranging from 0 to 12. At all time points, this composite score was highly correlated with drinking frequency (*r*-range =.83–.89), typical amount (*r*-range =.85–.89) and drinking 5 or more units (*r*-range =.90–.91). Scores on the AUDIT-C are found to be positively correlated with alcohol consumption, severity of alcohol problems, and the probability of alcohol use disorders (Rubinsky et al., 2013).

2.2.2. Predictor variable measured at t1

Energy drink consumption frequency was measured with one item: "Thinking about the last 30 days, how often did you drink energy drinks (e.g., Battery or Red Bull)?" Responses were indicated using six response categories that ranged from 0 = "Not at all", 1 = "1 day/month", 2 = "2–3 days/month", 3 = "1–2 days/week", 4 = "3–4 days/week", and 5 = "Every day or almost every day".

2.2.3. Potential confounding factors measured at t1

Family social status was measured using an adaptation of the MacArthur Scale of Subjective Social Status – Youth Version (Goodman et al., 2001). On a scale from the least (coded 1) to most affluent (coded 10), respondents indicated where in their neighborhoods they would place their families.

Parental non-cohabitation was measured by the item "Do your parents live together?" with a yes/no response option (coded 0/1).

Low parental knowledge was assessed by a single question which was based on established measures (Kerr and Stattin, 2000; Stattin and Kerr, 2000). The question was: "How much do your parents know about what you do in your free time?" The first two options ("They pretty often know what I'm doing", and "They always know what I'm doing") were coded 0, while the last three response options ("They think they know what I'm doing"; "Usually they don't know what I'm doing"; "Sometimes they know what I'm doing") were coded 1 to indicate low parental monitoring.

Sensation seeking was assessed using the 4-item Brief Sensation Seeking Scale (Stephenson et al., 2003; Vallone et al., 2007). Responses to items (e.g., "I like to do frightening things") were given using 5-point Likert type scales that ranged from 1 ("Completely disagree") to 5 ("Completely agree"). The average of individual item scores was used in the analysis. Cronbach's alpha for the scale was 0.79.

Behavioral problems were measured using seven items adopted from the Young in Norway Study (Frøyland et al., 2010). The items assess the frequency of behavioral problems such as stealing, lying, vandalism, and fighting during the past 12 months. Reponses were given on a 4-point scale ranging from "Never" (coded 0) to "5 or more times" (coded 3). The sum of item scores comprised a behavioral problems index.

Symptoms of depression during the past two weeks were measured using the 9-item Patient Health Questionnaire (PHQ-9) modified for use with adolescents (Johnson et al., 2002; Kroenke and Spitzer, 2002). Reponses were given on 4-point scales where 0 = "not at all" and 3 = "nearly every day". Scale properties have been examined in detail previously (Burdzovic Andreas and Brunborg, 2017). The sum of item scores was used in the analyses. Cronbach's alpha for the scale was 0.90.

Unstructured leisure time was measured with one item: "How often are you out at night (not with family or at an organized activity)?" Responses were given using six response options: "Not at all" (coded 1), "1 day per month" (coded 2), "2–3 days per month" (coded 3), "1–2 days per week" (coded 4), "3–4 times per week" (coded 5), and "5–7 days per week" (coded 6).

Sports practice frequency was measured with one item: "Thinking about the past 30 days, how often have you been to sports practice (e.g., soccer, handball, swimming). Responses were given using six response options: "Not at all" (coded 1), "1 day per month" (coded 2), "2–3 days per month" (coded 3), "1–2 days per week" (coded 4), "3–4 times per week" (coded 5), and "5–7 days per week" (coded 6).

Substance use. Ever use of cigarettes, snus (also known as moist snuff, a Swedish type of oral tobacco), e-cigarettes and cannabis were measured by simple yes/no questions, e.g., "Have you ever tried snus".

Gender, coded male = 0 and female = 1, and age in years were also recorded.

2.3. Analysis

We used Stata version 16 for data analysis (StataCorp, 2020). For the main analysis, we used growth curve models estimated with the "mixed" command in Stata (Rabe-Hesketh and Skrondal, 2012). The alcohol use variable was square root transformed to enable modeling of linear growth over time (Singer and Willett, 2003). The five annual assessments (coded t1 = 0, … t5 = 4) were used as a continuous indicator of time and comprised the first level of analysis. These repeated assessments were nested within individual participants; therefore participants comprised the second level of analysis.

In the first model (Model 1), we estimated the linear effect of energy drink consumption frequency on initial status (i.e., alcohol use at study baseline), and on annual rate of change in alcohol use, and included gender and age as covariates. In Model 2, we added family variables (family social status, parental non-cohabitation, low parental knowledge). In Model 3, we added individual characteristics (sensation-seeking, behavioral problems, symptoms of depression, unstructured

Table 1
Descriptive statistics and pairwise correlations for all the study variables.

No.	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Alcohol use T1	.43																			
2	Alcohol use T2	.37	.58																		
3	Alcohol use T3	.28	.42	.69																	
4	Alcohol use T4	.22	.32	.50	.70																
5	Alcohol use T5	.31	.32	.34	.27	.25															
6	Past 30-day energy drink use at T1	-.01	-.01	-.02	-.01	-.00	-.19														
7	Female gender T1	.21	.29	.31	.32	.25	.14	-.02													
8	Age T1	-.01	-.04	-.03	.03	.07	-.01	-.06	-.01												
9	Family social status T1	.06	.05	.06	.02	-.02	.04	-.04	-.01	-.07											
10	Parental non-cohabitation T1	.21	.16	.16	.12	.04	.27	-.11	-.01	-.09	.05										
11	Low parental knowledge T1	.18	.21	.25	.24	.18	.27	-.08	.06	-.02	.07	.17									
12	Sensation-seeking T1	.43	.27	.27	.24	.16	.39	-.09	.03	-.04	.09	.37	.28								
13	Behavioral problems T1	.19	.22	.22	.18	.15	.20	.25	.14	-.17	.04	.19	.20	.31							
14	Symptoms of depression T1	.19	.21	.25	.27	.22	.30	-.04	.04	.08	.06	.17	.24	.25	.09						
15	Unstructured leisure time T1	-.05	-.05	.00	.06	.10	-.10	.01	-.07	.19	-.03	-.13	-.01	-.05	-.18	.06					
16	Sports practice frequency T1	.46	.30	.29	.20	.15	.33	-.06	.15	-.05	.04	.24	.21	.41	.21	.18	-.12				
17	Ever smoked cigarettes T1	.50	.37	.30	.25	.20	.35	-.06	.15	-.02	.03	.21	.20	.37	.20	.16	-.09	.55			
18	Ever used snus T1	.39	.34	.38	.31	.24	.39	-.12	.20	-.01	.03	.20	.26	.36	.18	.21	-.05	.46	.45		
19	Ever used e-cigarettes T1	.39	.17	.17	.14	.09	.18	-.06	.08	-.03	.08	.14	.07	.30	.07	.11	-.06	.33	.34	.23	
20	Ever used cannabis T1	0–12	0–12	0–12	0–12	0–12	0–5	0–1	12.8–16.7	1–10	0–1	0–1	1–5	0–21	0–27	1–6	1–6	0–1	0–1	0–1	0–1
	Range	2878	2439	2260	1975	1550	2916	2916	2916	2753	2880	2906	2710	2900	2703	2883	2881	2878	2876	2873	2857
	N	0.28	0.87	1.75	2.86	3.78	0.76	56%	14.25	7.29	2%	18%	2.94	0.87	5.95	3.43	4.18	8%	9%	17%	1%
	Mean/%	1.04	1.78	2.34	2.75	2.77	1.16		0.85	1.71			1.02	1.65	5.48	1.53	1.62				
	SD																				

Note: Pearson's product moment correlations are reported for correlations between two continuous variables. Point-biserial correlations are reported for correlations between one binary (range = 0–1) and one continuous variable. Phi coefficients are reported for correlations between two binary variables.

leisure time, and sports practice frequency). In Model 4, we added substance use (ever smoked cigarettes, used snus, e-cigarettes or cannabis). To test effect modification by gender, we added gender by energy drink consumption frequency interaction terms in Model 5.

All continuous covariates added in Models 2–4 were centered at the mean. We used the default independent covariance structure for Stata's mixed command, such that the random effects part of the model included within-person residual variance, between-person variance for initial status, and between-person variance for rate of change. Models were estimated with maximum likelihood. We did not include a third level for school because the dependency in alcohol use between students from the same schools was very low (intraclass correlation = 0.02).

Initial alcohol use status and annual rate of change were estimated based on all available alcohol use observations. Missing alcohol use observations were handled by listwise deletion. Missing values on covariates were handled by multiple imputations, under the missing at random (MAR) assumption (Enders, 2010) with the predictive mean matching module in Stata (StataCorp, 2019). Ten datasets were created based on all study variables apart from use of energy drinks and alcohol. Linear predictions were computed with the "mimrgns" command (Klein, 2014).

3. Results

Descriptive statistics and pairwise correlations for all variables included in the analyses are presented in Table 1. The observed means for adolescent alcohol use were increasing over time. Alcohol use at t1 was positively correlated with age, sensation-seeking, behavioral problems, symptoms of depression, parental non-cohabitation, low parental knowledge, unstructured leisure time, and ever use of cigarettes, snus, e-cigarettes or cannabis. Sports practice frequency was weakly and negatively correlated with alcohol use at t1.

The distribution of frequency of energy drink consumption in the past 30 days at t1 was "Not at all" = 61%, "1 day" = 17%, "2–3 days" = 11%, "1–2 days/week" = 6%, "3–4 days/week" = 3%, and "Every day of almost every day" = 1%. Mean energy drink consumption frequency was higher for boys than girls, for adolescents with low parental knowledge, and for adolescents who had used cigarettes, snus, e-cigarettes, or cannabis. Energy drink consumption was also positively correlated with age, sensation-seeking, behavioral problems, symptoms of depression, and unstructured leisure time, and negatively correlated with sports practice frequency.

The results of the growth curve models are presented in Table 2. In Model 1, t1 energy drink consumption frequency was positively associated with initial alcohol use and with annual rate of change. Girls had higher initial alcohol use than boys, but the rate of change over time was similar. Older adolescents had higher initial alcohol use and greater increase in alcohol use over time.

All these estimates were virtually unchanged after including family factors in Model 2. The effect of t1 energy drink consumption on initial status was attenuated after including individual factors in Model 3 and substance use in Model 4, but the effect of energy drink consumption frequency at t1 on annual rate of change in alcohol use was virtually unchanged after adjustment for covariates. In sensitivity analysis, all the parameters for Model 4 were re-estimated four times, excluding observations at t2, t3, t4 and t5 respectively. The results showed that excluding parts of the data had marginal impact on the parameter estimates (see Supplementary table 1).

In Model 5 (Table 2), the interaction term for gender by energy drinks frequency was statistically significant for both initial status and rate of change. Estimated marginal means (back transformed to the original alcohol use scale with a possible range of 0–12) for all values of energy drink consumption frequency are presented numerically in Table 3 and displayed visually in Fig. 1. For boys there was almost no difference in initial alcohol use according to initial energy drink consumption. However, higher energy drink consumption at t1 was associated with somewhat greater increase in alcohol use over time. For girls, there were more notable differences between the energy drink groups at t1 compared to boys, but for girls, the differences between the groups remained almost the same to the end of the follow-up period.

Table 2
Growth curve models for the prospective association between energy drink consumption and alcohol use in adolescence.

	Model 1	Model 2	Model 3	Model 4	Model 5
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Fixed effects					
Initial status					
Intercept	-0.01 (0.01)	-0.04 (0.01)* *	0.04 (0.01)* *	-0.02 (0.01)* **	-0.02 (0.01)
Past 30-day energy drink use at T1	0.18 (0.01)* **	0.16 (0.01)* **	0.09 (0.01)* **	0.05 (0.01)* **	0.02 (0.01)*
Female gender	0.09 (0.02)* **	0.10 (0.02)* **	0.08 (0.02)* **	0.09 (0.02)* **	0.05 (0.02)*
Age (T1)	0.16 (0.01)* **	0.17 (0.01)* **	0.16 (0.01)* **	0.12 (0.01)* **	0.12 (0.01)* **
Past 30-day energy drink use at T1 x gender					0.06 (0.02)* **
Rate of change					
Intercept	0.39 (0.01)* **	0.39 (0.01)* **	0.40 (0.01)* **	0.40 (0.01)* **	0.38 (0.02)* **
Past 30-day energy drink use at T1	0.01 (0.01)* *	0.02 (0.01)* *	0.01 (0.01)	0.02 (0.01)*	0.03 (0.01)* **
Female gender	0.02 (0.01)	0.02 (0.01)	0.01 (0.01)	0.01 (0.01)	0.04 (0.02)*
Age (T1)	0.06 (0.01)* **	0.06 (0.01)* **	0.06 (0.01)* **	0.06 (0.01)* **	0.06 (0.01)* **
Past 30-day energy drink use at T1 x gender					-0.04 (0.01)* *
Random effects					
Residual within-variance (SD)	0.54 (0.00)	0.54 (0.00)	0.54 (0.00)	0.54 (0.00)	0.54 (0.00)
Variance in initial status (SD)	0.31 (0.01)	0.29 (0.01)	0.24 (0.01)	0.17 (0.01)	0.17 (0.01)
Variance in rate of change (SD)	0.22 (0.01)	0.22 (0.01)	0.22 (0.00)	0.22 (0.00)	0.22 (0.00)

Note: For all models *N individuals* = 2916, *N observations* = 11102, observations per individual = 3.8; * **p < 0.001 * *p < 0.01 *p < 0.05; The outcome variable values are square root transformation of alcohol use scores (range = 0–3.46); Family factors (family social status, parental non-cohabitation, low parental knowledge) added in Model 2; Individual factors (sensation-seeking, behavioral problems, symptoms of depression, unstructured leisure time, sports practice frequency) added in Model 3. Substance use (ever use of cigarettes, snus, e-cigarettes, or cannabis) added in Model 4. Missing values on covariates are handled by multiple imputations.

4. Discussion

This study investigated the longitudinal association between energy drink consumption at age 13–15 and development in alcohol use over the next four years, up to age 17–19. After including a range of potential confounders (family factors, individual characteristics, and substance use), the estimates from growth curve modeling overall indicated small differences in the development of alcohol use between adolescents with different energy drink consumption. The effect became smaller after accounting for potential confounders, which suggests that the raw association is at least partly due to confounding factors. The largest

Table 3
Back transformed estimated marginal mean alcohol use in adolescence for different energy drink consumption groups at T1 (age 13–15 years).

	T1: Age 13–15	T2: Age 14–16	T3: Age 15–17	T4: Age 16–18	T5: Age 17–19
Past 30-day energy drink use					
Boys					
None	0.003	0.18	0.62	1.35	2.31
1 day/month	0.01	0.23	0.77	1.64	2.82
2–3 days/month	0.01	0.28	0.94	1.96	3.35
1–2 days/week	0.02	0.35	1.10	2.31	3.92
3–4 days/week	0.02	0.42	1.30	2.69	4.58
Every day or almost every day	0.03	0.49	1.51	3.10	5.24
Boys' average	0.01	0.21	0.72	1.54	2.66
Girls					
None	0.01	0.26	0.85	1.74	2.99
1 day/month	0.04	0.35	0.98	1.93	3.24
2–3 days/month	0.07	0.45	1.12	2.13	3.46
1–2 days/week	0.12	0.55	1.30	2.34	3.72
3–4 days/week	0.18	0.67	1.46	2.59	4.00
Every day or almost every day	0.26	0.81	1.66	2.82	4.28
Girls' average	0.03	0.32	0.94	1.88	3.17

Note: Alcohol use range = 0–12

attenuation occurred after accounting for personality factors and other substance use, suggesting that the observed association between energy drink consumption and alcohol use is at least partly due to factors that place adolescents at greater risk of several types of risky behavior. This is in line with common liability theory (Vanyukov et al., 2012) and problem behavior theory (Jessor and Jessor, 1977).

Previous prospective studies have found both moderate to strong effects (Barrense-Dias et al., 2016; Marmorstein, 2019; Miyake and Marmorstein, 2015) and small effects (Choi et al., 2016) of energy drink consumption on future alcohol use. Our results are in line with the latter. The reason for the discrepancy between our study and studies that have found stronger effects might be that our modeling strategy included multiple follow-ups that allowed more precise estimation of change over time, and the fact that we included more potential confounding factors. Other potential explanations are cultural differences, differences in time between follow-ups, and differences in alcohol use measurement.

It has been suggested that parents, teachers, and prevention professionals could use energy drink consumption to screen for adolescents at risk of future alcohol misuse (Barrense-Dias et al., 2016; Marinoni et al., 2022). The results of our study suggest that this approach may have limited benefits because the excess risk associated with regular consumption of energy drinks in early adolescence is probably small, and because of the small expected reduction in overall adolescent alcohol use potentially gained from efforts to reduce adolescent energy drinks consumption.

4.1. Strengths and limitations

Strengths of the current study include a large and diverse sample, and multiple assessments that allowed growth curve modeling, a methodology that is superior to methods based on only two time points (Singer and Willett, 2003). In addition, we included more potential confounding variables than in previous studies, which strengthens the internal validity. However, some limitations need to be noted. We measured the frequency and not the total intake of energy drinks, and hence did not capture the full range of energy drink consumption. We did not measure the mixing of energy drinks with alcoholic beverages; therefore, we were unable to isolate unique vs. potentially synergistic effects. The last two assessments coincided with the COVID-19 pandemic, potentially distorting the normative development in alcohol consumption. However, sensitivity analysis indicated that omitting either of these time points had little impact on the parameter estimates. All variables were measured using self-reports, which is associated with measurement error due to biased recall and socially desirable responding. Measurement error in exposure and outcome variables tends to bias regression estimates downwards, and error in measurement of potential confounders can diminish the control of confounding (Armstrong, 1998). Finally, as is common in longitudinal studies, not all those recruited participated at all time points, and we must remain cautious about generalizing our results to the entire Norwegian adolescent population or beyond.

5. Conclusion

Greater consumption of energy drinks among Norwegian adolescents aged 13–15 is associated with higher concurrent alcohol use and greater increase in alcohol use over time when studied up to age 17–19. However, this effect is rather modest. Preventing energy drink consumption may only play a small role in efforts to prevent adolescent alcohol use.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

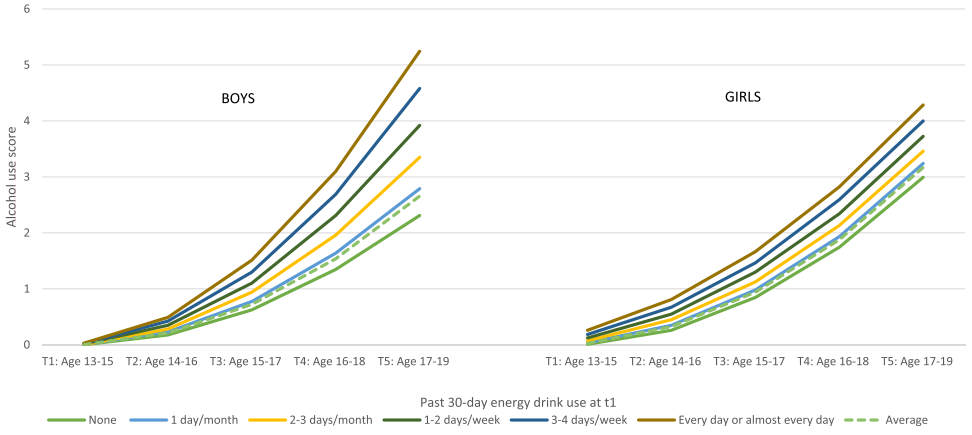

Fig. 1. Mean alcohol use (possible range 0–12) from t1-t5 for adolescents with different energy drink use at t1 presented separately for boys and girls.

Author disclosures

None.

Conflict of interest

No conflict declared.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.drugalcdep.2022.109666.

References

Aranda, M., Morlock, G., 2006. Simultaneous determination of riboflavin, pyridoxine, nicotinamide, caffeine and taurine in energy drinks by planar chromatography-multiple detection with confirmation by electrospray ionization mass spectrometry. J. Chromatogr. A 1131 (1), 253–260.

Armstrong, B.G., 1998. Effect of measurement error on epidemiological studies of environmental and occupational exposures. Occup. Environ. Med 55 (10), 651–656.

Barrense-Dias, Y., Berchtold, A., Akre, C., Surís, J.C., 2016. Consuming energy drinks at the age of 14 predicted legal and illegal substance use at 16. Acta Paediatr. 105 (11), 1361–1368.

Brunborg, G.S., Scheffels, J., Tokle, R., Buvik, K., Kvaavik, E., Burdzovic Andreas, J., 2019. Monitoring young lifestyles (MyLife) - a prospective longitudinal quantitative and qualitative study of youth development and substance use in Norway. BMJ Open 9 (10), e031084.

Brunborg, G.S., Halkjelsvik, T.B., Moan, I.S., 2022. Sports participation and alcohol use revisited: a longitudinal study of Norwegian postmillennial adolescents. J. Adolesc. 94, 587–599.

Burdzovic Andreas, J., Brunborg, G.S., 2017. Depressive symptomatology among Norwegian adolescent boys and girls: the patient health Questionnaire-9 (PHQ-9) psychometric properties and correlates. Front. Psychol. 8, 887.

Choi, H.J., Wolford-Clevenger, C., Brem, M.J., Elmquist, J., Stuart, G.L., Pasch, K.E., Temple, J.R., 2016. The temporal association between energy drink and alcohol use among adolescents: a short communication. Drug Alcohol Depend. 158, 164–166.

Dawodu, A., Cleaver, K., 2017. Behavioural correlates of energy drink consumption among adolescents: a review of the literature. J. Child Health Care 21 (4), 446–462.

Enders, C.K., 2010. Applied missing data analysis. Guilford press.

Frøyland, L.R., Strand, N.P., von Soest, T., 2010. Young in Norway - cross-sectional: Documentation of design, variables and scales. NOVA, Oslo.

Goodman, E., Adler, N.E., Kawachi, I., Frazier, A.L., Huang, B., Colditz, G.A., 2001. Adolescents' perceptions of social status: development and evaluation of a new indicator. Pediatrics 108 (2) e31-e31.

Hawkins, J.D., Catalano, R.F., Miller, J.Y., 1992. Risk and protective factors for alcohol and other drug problems in adolescence and early adulthood: Implications for substance abuse prevention. Psychol. Bull. 112 (1), 64–105.

Hill, K.G., White, H.R., Chung, I.J., Hawkins, J.D., Catalano, R.F., 2000. Early adult outcomes of adolescent binge drinking: person-and variable-centered analyses of binge drinking trajectories. Alcohol.: Clin. Exp. Res. 24 (6), 892–901. ⟨https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1847635/⟩.

Hsu, C.W., Chen, C.Y., Wang, C.-S., Chiu, T.H., 2009. Caffeine and a selective adenosine A2A receptor antagonist induce reward and sensitization behavior associated with increased phospho-Thr75-DARPP-32 in mice. Psychopharmacology 204 (2), 313–325.

Inchley, J., Currie, D., Budisavljevic, S., Torsheim, T., Jåstad, A., Cosma, A., Kelly, C., Arnarsson, Á.M., Barnekow, V., Weber, M.M., 2020. Spotlight on adolescent health and well-being. Findings from the 2017/2018 Health Behaviour in School-aged Children (HBSC) survey in Europe and Canada. International report. Volume 1. Key findings. WHO Regional Office for Europe Copenhagen.

Jessor, R., Jessor, S.L., 1977. Problem Behavior and Psychosocial Development: A Longitudinal Study of Youth. Academic Press, New York.

Johnson, J.G., Harris, E.S., Spitzer, R.L., Williams, J.B., 2002. The patient health questionnaire for adolescents: validation of an instrument for the assessment of mental disorders among adolescent primary care patients. J. Adolesc. Health 30 (3), 196–204.

Kaldenbach, S., Strand, T.A., Solvik, B.S., Holten-Andersen, M., 2021. Social determinants and changes in energy drink consumption among adolescents in Norway, 2017–2019: a cross-sectional study. BMJ Open 11 (8), e049284.

Kerr, M., Stattin, H., 2000. What parents know, how they know it, and several forms of adolescent adjustment: further support for a reinterpretation of monitoring. Dev. Psychol. 36 (3), 366.

Klein, D., 2014. MIMRGNS: Stata module to run margins after mi estimate, Statistical Software Components S457795. Boston College Department of Economics, Boston, MA.

Kroenke, K., Spitzer, R.L., 2002. The PHQ-9: A new depression diagnostic and severity measure. Psychiatr. Ann. 32 (9), 509–515.

Lubman, D.I., Yücel, M., Hall, W.D., 2007. Substance use and the adolescent brain: a toxic combination? J. Psychopharmacol. 21 (8), 792–794.

Marinoni, M., Parpinel, M., Gasparini, A., Ferraroni, M., Edefonti, V., 2021. Psychological and socio-educational correlates of energy drink consumption in children and adolescents: a systematic review. European Journal of Pediatrics.

Marinoni, M., Parpinel, M., Gasparini, A., Ferraroni, M., Edefonti, V., 2022. Risky behaviors, substance use, and other lifestyle correlates of energy drink consumption in children and adolescents: a systematic review. Eur. J. Pediatr.

Marmorstein, N.R., 2019. Investigating associations between caffeinated beverage consumption and later alcohol consumption among early adolescents. Addict. Behav. 90, 362–368.

Miyake, E.R., Marmorstein, N.R., 2015. Energy drink consumption and later alcohol use among early adolescents. Addict. Behav. 43, 60–65.

Mokdad, A.H., Forouzanfar, M.H., Daoud, F., Mokdad, A.A., El Bcheraoui, C., Moradi-Lakeh, M., Kyu, H.H., Barber, R.M., Wagner, J., Cercy, K., Kravitz, H., Coggeshall, M., Chew, A., O'Rourke, K.F., Steiner, C., Tuffaha, M., Charara, R., Al-Ghamdi, E.A., Adi, Y., Afifi, R.A., Alahmadi, H., AlBuhairan, F., Allen, N., AlMazroa, M., Al-Nehmi, A.A., AlRayess, Z., Arora, M., Azzopardi, P., Barroso, C., Basulaiman, M., Bhutta, Z.A., Bonell, C., Breinbauer, C., Degenhardt, L., Denno, D., Fang, J., Fatusi, A., Feigl, A.B., Kakuma, R., Karam, N., Kennedy, E., Khoja, T.A.M., Maalouf, F., Obermeyer, C.M., Mattoo, A., McGovern, T., Memish, Z.A., Mensah, G. A., Patel, V., Petroni, S., Reavley, N., Zertuche, D.R., Saeedi, M., Santelli, J., Sawyer, S.M., Ssewamala, F., Taiwo, K., Tantawy, M., Viner, R.M., Waldfogel, J., Zuñiga, M.P., Naghavi, M., Wang, H., Vos, T., Lopez, A.D., Al Rabeeah, A.A., Patton, G.C., Murray, C.J.L., 2016. Global burden of diseases, injuries, and risk factors for young people's health during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. In: The Lancet, 387, pp. 2383–2401.

Pape, H., Rossow, I., Brunborg, G.S., 2018. Adolescents drink less: How, who and why? A review of the recent research literature. Drug Alcohol Rev. 37, S98–S114.

Rabe-Hesketh, S., Skrondal, A., 2012. Multilevel and Longitudinal Modeling Using Stata, 3rd ed.,. Stata Press, College Station, TX.

Reissig, C.J., Strain, E.C., Griffiths, R.R., 2009. Caffeinated energy drinks—a growing problem. Drug Alcohol Depend. 99 (1), 1–10.

Rogosa, D., Brandt, D., Zimowski, M., 1982. A growth curve approach to the measurement of change. Psychol. Bull. 92 (3), 726–748.

Rubinsky, A.D., Dawson, D.A., Williams, E.C., Kivlahan, D.R., Bradley, K.A., 2013. AUDIT-C scores as a scaled marker of mean daily drinking, alcohol use disorder severity, and probability of alcohol dependence in a U.S. general population sample of drinkers. Alcohol. Clin. Exp. Res. 37 (8), 1380–1390.

Saunders, J.B., Aasland, O.G., Babor, T.F., De La Fuente, J.R., Grant, M., 1993. Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption-II. Addiction 88 (6), 791–804.

Singer, J.D., Willett, J.B., 2003. Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence. Oxford University Press.

StataCorp, 2019. Stata Multiple-imputation Reference Manual: Release 16. Author, College Station, TX.

StataCorp, 2020. Stata Statistical Software: Release 16. StataCorp LLC, College Station, TX.

Stattin, H., Kerr, M., 2000. Parental monitoring: a reinterpretation. Child Dev. 71 (4), 1072–1085.

Stephenson, M.T., Hoyle, R.H., Palmgreen, P., Slater, M.D., 2003. Brief measures of sensation seeking for screening and large-scale surveys. Drug Alcohol Depend. 72 (3), 279–286.

Sweeney, M.M., Meredith, S.E., Evatt, D.P., Griffiths, R.R., 2017. Effects of caffeine on alcohol reinforcement: beverage choice, self-administration, and subjective ratings. Psychopharmacology 234 (5), 877–888.

Toumbourou, J.W., Rowland, B., Williams, J., Smith, R., Patton, G.C., 2019. Community intervention to prevent adolescent health behavior problems: evaluation of communities that care in Australia. Health Psychol. 38 (6), 536–544.

Vallone, D., Allen, J.A., Clayton, R.R., Xiao, H., 2007. How reliable and valid is the brief sensation seeking scale (BSSS-4) for youth of various racial/ethnic groups? Addiction 102 (s2), 71–78.

Van Walraven, C., Hart, R.G., 2008. Leave'em alone-why continuous variables should be analyzed as such. Neuroepidemiology 30 (3), 138.

Vanyukov, M.M., Tarter, R.E., Kirillova, G.P., Kirisci, L., Reynolds, M.D., Kreek, M.J., Conway, K.P., Maher, B.S., Iacono, W.G., Bierut, L., Neale, M.C., Clark, D.B., Ridenour, T.A., 2012. Common liability to addiction and "gateway hypothesis": theoretical, empirical and evolutionary perspective. Drug Alcohol Depend. 123, S3–S17.

Yasuma, N., Imamura, K., Watanabe, K., Nishi, D., Kawakami, N., Takano, A., 2021. Association between energy drink consumption and substance use in adolescence: a systematic review of prospective cohort studies. Drug Alcohol Depend. 219, 108470.