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ORIGINAL ARTICLE

Energy drink consumption, health complaints and late bedtime among young adolescents

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Abstract
Objectives Energy drinks contain large amounts of caffeine. Their effects on adolescent well-being are poorly known. We examined the relationship of energy drink consumption with health complaints and late bedtime among 13-year-olds.
Methods A classroom survey was conducted on all 7th graders in the Helsinki metropolitan region, Finland (73 % responded; $n = 9446$). Logistic regression analysis and structural equation modeling (SEM) were used.
Results The prevalence of health complaints increased as energy drink consumption increased from non-consumers to several times/day. Late bedtime (≥11 PM) increased correspondingly. Those consuming energy drinks several times/day exhibited increased odds of experiencing daily health complaints compared with non-consumers: headache OR (adjusted) = 4.6 (2.8–7.7), sleeping problems OR = 3.6 (2.2–5.8), irritation OR = 4.1 (2.7–6.1), tiredness/fatigue OR = 3.7 (2.4–5.7), and late bedtime OR = 7.8 (5.7–10.9). In SEM, energy drink consumption had a direct effect on health complaints and late bedtime and an indirect effect on health complaints via late bedtime.
Conclusions Energy drinks, late bedtime, and health complaints form a behavior pattern that is worth considering in schools, home and clinical settings when adolescents complain about headaches, problems with sleeping and corresponding symptoms.

Keywords Energy drinks · Adolescents · Caffeine · Health complaints · Late bedtime

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Introduction

Energy drinks represent a relatively new product in the soft drink market, with a rapid growth in consumption during the last decade (Simon and Mosher 2007). Approximately 5 % of adolescents and young adults consume energy drinks on a daily basis, and 30–70 % of adolescents consume these drinks less often than daily (Seifert et al. 2011; Zucconi et al. 2013; Kristjansson et al. 2014; Fakhouri et al. 2012).

Energy drinks differ from other soft drinks based on their high caffeine content. Their ingredients and adverse health effects among children and adolescents have raised concerns daily (Seifert et al. 2011; Oddy and O'Sullivan 2009). Top selling energy drinks contain approximately 75–160 mg of caffeine per can, but drinks with much higher levels are available (Reissig et al. 2009). Due to the

smaller body weight of children and adolescents, their relative caffeine intake is increased compared with adults, thus increasing the risk of adverse effects.

Caffeine is an addictive substance with withdrawal symptoms that can last for several days (Juliano and Griffiths 2004). In children who are unaccustomed to caffeine, high doses can cause nervousness, jitteriness, stomach ache and nausea (Hughes and Hale 1998). Caffeinated sugar-containing drinks have been related to physical complaints (headaches, stomach aches, sleeping problems, and low appetite) among children, and a stronger effect is observed for energy drinks compared with cola drinks (Kristjansson et al. 2014). A recent review concluded that high caffeine intake (e.g., >5 mg/kg body weight/day) increases the risk of anxiety and withdrawal symptoms among children, whereas smaller amounts may improve cognitive function and sports performance (Ruxton 2013). The study concluded that children and adolescents should limit their daily caffeine consumption to 2.5 mg/kg of body weight.

Caffeine acts through the central nervous system and disrupts sleep (Dunwiddie and Masino 2001). Regular caffeine intake or high doses as well as caffeine ingestion in the evening can cause sleep disturbances, such as waking up early or disrupted sleep during the night (Bryant and Wolfson 2010; Orbeta et al. 2006). Along with later bedtimes in modern societies, the insufficiency of sleep among children and adolescents has become a topic of considerable concern (Hagenauer et al. 2009; Matricciani et al. 2012; Carskadon 2011). Inadequate sleep is associated with negative outcomes in several areas of health and functioning, including somatic and psychosocial health (Touitou 2013; Darchia and Cervena 2014, Nuutinen et al. 2014). Insufficient sleep has also been found to impact various developmental processes, cognitive abilities and physical and psychosocial functioning (Brand and Kirov 2011; Liu and Zhou 2002; Touchette et al. 2007). It has also been shown to negatively influence school performance (Wolfson and Carskadon 2003; Kronholm et al. 2011). Also a link between short sleep and risk taking behavior has been observed (Shochat et al. 2014). This may take place through the connections between the development of the cognitive control and decision-making system, the functioning and development of which may be disturbed by insufficient sleep. Short sleep may also increase sensation-seeking and lower impulse control (Peach and Gaultney 2013).

Sleeping problems are common in adolescents' and insufficient sleep due to sleeping problems can cause daytime tiredness (Liu et al. 2005; Gradisar et al. 2011). Among those is the delayed sleep phase disorder, which may be related with a delay in the circadian clock, and is depicted in persistent inability in falling asleep at earlier times and difficulty in waking up in the morning (Micic et al. 2015). There is some evidence about the relationship of the disorder with increased use of caffeine compared to those without the disorder (Lovato et al. 2013). In general, along with the shortening of sleep time, daytime sleepiness among the young has increased (Carskadon 2011). In addition to caffeine-containing energy drinks, staying online or performing other media activities late at night is associated with daytime sleepiness (Calamaro et al. 2009). Energy drinks are a potential method to stay awake beyond earlier bedtime.

Our aim was to study the relationship of energy drink consumption with health complaints and late bedtime among young adolescents. Health complaints related to caffeine consumption (Juliano and Griffiths 2004), namely headache, irritation, sleeping problems, and tiredness/fatigue, are used. Based on earlier studies, we tested the hypothesis that energy drink consumption increases such health complaints. We further tested the hypothesis that the relationship between energy drink consumption and health complaints is mediated via late bedtime.

Methods

Sample and data collection

The present study was based on a school survey conducted in 2011 in the Helsinki metropolitan region of Finland, which spans 14 municipalities. The purpose of the study was to analyze how educational outcomes and children's health and well-being are related and vary across schools. All 7th graders (13 years old) were invited to participate. The recruitment occurred through the educational authorities of the municipalities, each of which gave permission for the study. The Ethical Committee of the National Institute of Health and Welfare approved the protocol. Because the study was part of normal school work, parental consent was not required. However, two of the municipalities obliged parental consent statements, which were collected. An informational letter was delivered to parents in the remaining 12 municipalities.

Of the recruited 7th graders ($n = 13{,}012$), 9497 participated in the study, resulting in a response rate of 73 %. Special schools and classes were excluded from the sample (students $n = 163$, 1.25 %) because of the students' expected difficulty with answering the questions. Most schools did not participate at all and altogether only 30 students answered. Special schools are for children with serious learning difficulties, intellectual disabilities or are situated with pediatric hospital wards. Five schools from the city of Helsinki did not participate ($n = 330$; 2.5 %). Two of the schools had computer classes under

construction. One school did not receive the individual passwords in time, and two administratively independent schools were not interested in participating. The other non-respondents included those absent from school on the survey day (typically 10–15 % of students each day) and those who refused to participate or whose parents' consent statement was negative or not received. The participating schools did not have information about whether the pupil had refused to participate or was absent from school. Incomplete and unreliable questionnaires (most questions empty; answers for open-ended questions consisted of profanities and in most answers the extreme choices were selected, e.g., all daily health complaints, daily smoking, highest school marks) were excluded ($n = 42$, 0.3 %). In addition, nine respondents with missing gender information were not included in the study, leaving 9446 respondents.

The data were gathered as part of the school routine. The participants completed the survey online in computer classrooms using their personal user names and passwords created by the researchers and delivered by the supervising teachers. The survey consisted of questions regarding well-being, health, health behavior, school, and family background.

Measures

The question concerning the frequency of energy drink consumption was phrased: "How often do you drink energy drinks?" Possible responses included "not at all", "once a week or less", "approximately 3 to 4 times a week", "approximately once a day", and "several times a day". The participants were asked whether they had experienced health complaints with the question: "In the last 6 months, have you had any of the following health complaints and how often?" Possible responses included "rarely or not at all", "approximately once a month", "approximately once a week", and "nearly every day". Of the ten health complaints (headache, irritation or outburst of anger, trouble falling asleep or waking at night, tiredness/fatigue, neck–shoulder pain, low back pain, stomachache, tension or nervousness, feeling dizzy, and trembling of hands), the first four were selected for the analysis given their relationship to caffeine consumption (Juliano and Griffiths 2004).

The time of going to bed on school days was asked via a structured question, and possible responses included times with 30-min intervals. We defined a late bedtime as 11 PM or later as this response is indicative of less than 8 h of sleep given the early school start in the Helsinki region (typically 8 or 8:15 AM).

Socio-demographic background variables were used in the analyses as potential confounders as they are found to be related with health behaviors of adolescents (e.g., Whitehead et al. 2015). In addition to gender, parents' education (high, middle, or low; missing answers, 14.5 %) was composed of the mother's and father's educations by choosing the highest one. Family structure was dichotomized to indicate whether the parents were living together (nuclear family) or not (non-nuclear family; data missing 0.7 %). Academic achievement was measured by the mean of self-reported school marks for five school subjects (mother tongue, mathematics, first foreign language, history, and chemistry; missing, 1.6 %) at the end of 6th grade. The mean values were categorized in four categories based on the evaluation system in Finnish schools ranging from poor to excellent. Chronic illness was also considered as a potential confounder and was measured by asking the children whether they had a long-term disease (no/yes).

Statistical analysis

Logistic regression analysis was used to study how caffeine-induced health complaints (headache, sleeping problems, irritation, and tiredness/fatigue) and late bedtime were associated with energy drink consumption. Dichotomized health complaints (having a health complaint daily or not having one daily) and late bedtime were studied separately as dependent variables. Energy drink consumption with five categories (several times a day, once a day, 3–4 times a week, once a week or less often, and not at all) served as the independent variable. The reference group included adolescents who did not consume energy drinks. The first model was crude, and the second model was adjusted for gender, academic achievement, parents' education, family structure and chronic illness as possible confounding factors. The strengths of the associations were expressed by odds ratios (OR) and their 95 % confidence intervals (CI), and for both crude and adjusted models, the Nagelkerke pseudo R-squares were given.

Structural equation modeling (SEM) was used to study the direct effects of the observed and latent variables (two endogenous and one exogenous). The variables included energy drink consumption, late bedtime, and daily health complaints. Of these variables, daily health complaints was a latent variable, and the others were observed variables. We tested the hypothesis that the frequency of energy drink consumption is related to health complaints and going to bed late. Furthermore, we hypothesized that an indirect effect from energy drink consumption on health complaints occurred through late bedtimes. Because of the larger amount of health complaints in girls (e.g., Currie et al. 2012), the models were fitted separately in boys and girls. The adjustment for confounders in the logistic regression caused only minor changes in ORs, and thus no confounders were considered in these analyses. The model is represented with standardized coefficients, and the

goodness-of-fit statistics consists of the root mean square error of approximation (RMSEA) and weighted root mean square residual (WRMR). The analysis was conducted and bootstrapped using Mplus 5.21 (Muthén and Muthén 2012). SPSS 21.0 was used for the other analyses (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). The associations between energy drink consumption and health complaints were assessed using Chi-square tests, and p values < 0.05 were considered statistically significant.

Results

Of all participants, 2.4 % consumed energy drinks several times a day, and 5.2 % consumed them daily. Boys consumed energy drinks more often than girls. Approximately half of all the respondents (44.6 %) were energy drink consumers (Table 1). Daily symptoms were more common among girls than boys. Among girls, 6.1 % reported headache, 11.1 % sleeping problems, 8.3 % irritation, and 10.6 % tiredness/fatigue. The corresponding percentages among boys were 3.2, 6.2, 4.3, and 5.8 %. Twenty-four percent of the adolescents went to bed later than 11 PM (24.6 % of boys and 22.8 % of girls).

The percentage of adolescents suffering from any of the four health complaints or going to bed late increased along with the increasing frequency of energy drink consumption (Table 2). Those who consumed energy drinks several times a day exhibited the highest prevalence of health complaints, whereas non-drinkers had the lowest. Correspondingly, the proportion of adolescents going to bed late increased along with the increasing frequency of energy drink consumption. The results were similar for both genders. All Chi-square tests were statistically significant ($p < 0.001$).

In the logistic regression models, the ORs for all daily health complaints increased along with the increasing frequency of energy drink consumption (Table 3). The results did not change after adjusting for gender, parents' education, family structure, school achievement, and chronic illness. Compared with non-drinkers, the ORs were 3- to 4-fold increased in those who consumed energy drinks several times a day. The largest difference was observed for headache.

Table 1 Frequency of energy drink consumption among 13-year-old adolescents in Helsinki metropolitan region, Finland (2011) by gender

Frequency of energy drink consumption	Boys (%)	Girls (%)	Total (%)
Several times a day	3.6	1.2	2.4
Approximately, once a day	4.2	1.5	2.8
Approximately, 3–4 times a week	10.8	4.1	7.4
Once a week or less	38.7	25.7	32.0
Not at all	42.6	67.5	55.4
Total %	100.0	100.0	100.0
n	4505	4729	9234
p value[a]	<0.001		

[a] Chi-square test

The structural equation model was fitted to the data to test the hypotheses that energy drink consumption has a direct effect on health complaints and late bedtime and an indirect effect on health complaints through late bedtime (Fig. 1). Figure 1 presents the standardized coefficients of the associations. The models were fitted separately for boys and girls. Neither of the hypotheses was rejected. Energy drink consumption was strongly related to late bedtime both for girls (0.339) and boys (0.325) and moderately related to health complaints (girls 0.122; boys 0.125). Late bedtime had a direct effect on health complaints in both genders (girls 0.264; boys 0.363). The direct effect of energy drinks on health complaints was stronger than the indirect effect among boys (0.122 vs. 0.090) and approximately the same among the girls (0.125 vs. 0.118). The total effect was 0.211 for boys and 0.243 for girls. All of the associations in the model were significant for both genders ($p < 0.001$). The RMSEA (<0.001) indicated a good fit to the data. The WRMR was 0.762 for girls and 0.916 for boys.

Discussion

The consumption of energy drinks was related to the increased risk of health complaints and late bedtime: the more frequent the consumption, the more common the caffeine-related health complaints and late bedtime. The relationship between energy drinks and health complaints was partly mediated through going to bed late.

Our results support the earlier study by Kristjansson et al. (2014) that energy drink consumption among adolescents is related to increased physical complaints. Our results also demonstrated that the relationship between energy drinks and health complaints was partly mediated through late bedtime. This novel finding suggests that energy drinks may be consumed by youth to stay awake late in the evening or through to the next morning when staying online for popular activities, such as social media. Sleep duration has in earlier research been observed to mediate the association between computer use and symptoms (Nuutinen et al. 2014). The reasons for the need to stay up late vary from preparation for school exams to social gatherings and playing digital games with friends from different time zones throughout the world. An example of such activities includes LAN (Local Area

Table 2 Percentage (%) of 13-year-old adolescents in Helsinki metropolitan region, Finland (2011) reporting daily health complaints and late bedtime, by energy drink consumption and gender

Energy drink consumption	Headache	Sleeping problems	Irritation	Tiredness/ fatigue	Late bedtime
Boys					
Several times a day ($n = 154$)	12.3	16.2	9.7	13.2	58.4
Approx. once a day ($n = 187$)	6.4	9.6	5.3	11.8	46.5
Approx. 3–4 times a week ($n = 479$)	4.8	7.7	6.3	8.5	39.9
Once a week or less ($n = 1727$)	2.8	5.3	3.8	5.0	26.8
Not at all ($n = 1907$)	1.7	5.4	3.7	4.5	13.4
p value[a]	<0.001	<0.001	<0.001	<0.001	<0.001
Girls					
Several times a day ($n = 55$)	21.8	36.4	20.0	32.7	61.8
Approx. once a day ($n = 68$)	10.3	17.6	11.8	19.1	61.8
Approx. 3–4 times a week ($n = 196$)	11.7	19.4	15.8	17.3	49.0
Once a week or less ($n = 1216$)	8.3	14.5	12.9	15.1	34.3
Not at all ($n = 3183$)	4.6	8.8	5.8	8.0	15.4
p value[a]	<0.001	<0.001	<0.001	<0.001	<0.001

[a] Chi-square test

Network) parties, (which are small or large temporary gatherings of people with computers or compatible game consoles to play multiplayer video games. Energy drinks might be used to stave off sleep for hours over normal bedtime. Also, adolescents who are active in sports often have training sessions in the evening or even late evening. In this context, energy drinks are may be considered a source of fluid, energy, refreshment and endurance; physically active youth consume energy drinks more often than less active (Bulut et al. 2014; Kumar et al. 2015).

In our study, 5.2 % of 13-year-old schoolchildren consumed energy drinks daily, and approximately half of these students consumed these drinks less often. The frequency of energy drink consumption among Finnish adolescents was comparable with the consumption in other Western countries, and more frequent consumption among boys compared with girls was also observed in our study (Seifert et al. 2011, Kristjansson et al. 2014).

The consumption of energy drinks was associated with an elevated risk of health complaints with a dose–response relationship. The health complaints reported in this study are related to caffeine consumption (Juliano and Griffiths 2004), and the dose–response relationship suggests that the high caffeine content in energy drinks may be involved in the increase of symptoms. Furthermore, caffeine is related to sleep disturbances (Dunwiddie and Masino 2001) and may be among the reasons for the later bedtime among energy drink consumers. The symptoms caused by staying awake over earlier bedtime and not getting sufficient sleep found in other studies (e.g., Nuutinen et al. 2014) are similar to those measured in our study, potentially reflecting caffeine-related health complaints (Juliano and Griffiths 2004). It is difficult to separate the effects of caffeine in energy drinks from the effects of late bedtime. However, our results suggest that both mechanisms may be involved here. In the future, a longitudinal research design with two or more measurement points could be used to separate the effects of energy drink use and bedtime on the amount of health complaints, e.g., by latent growth analysis.

Strengths and weaknesses

The study was conducted in the Helsinki metropolitan region, and all 7th graders in all schools in the region were recruited. The study mainly represents the urbanized adolescent population. The response rate was good. Non-responders mainly consisted of children who were absent from school and those who did not provide parental consent as well as students from a few schools that did not participate. However, these non-responders are unlikely to have a major effect on the studied relationships. We cannot exclude the possibility of selection bias of those who consumed energy drinks, went to bed late and had health complaints. If such a selection bias exists, it would dilute the observed relationships.

Self-reported data have weaknesses as measured behaviors are not always stable during a long period of time. This lapse in time results in random error, which may weaken the studied associations. With a cross-sectional design, it is not possible to determine whether the temporal order of the energy drinks and health complaints differs from the hypothesis.

Table 3 The relation of energy drink consumption to health complaints and late bedtime in Helsinki metropolitan region, Finland (2011)

	Headache		Sleeping problems		Irritation		Tiredness/fatigue		Late bedtime	
	Crude OR (95 % CI)	Adjusted OR (95 % CI)	Crude OR (95 % CI)	Adjusted OR (95 % CI)	Crude OR (95 % CI)	Adjusted OR (95 % CI)	Crude OR (95 % CI)	Adjusted OR (95 % CI)	Crude OR (95 % CI)	Adjusted OR (95 % CI)
Energy drink consumption										
Several times a day	4.8 (3.2–7.2)	4.6 (2.8–7.7)	2.8 (1.9–4.3)	3.6 (2.2–5.8)	3.5 (2.5–4.9)	4.1 (2.7–6.1)	3.1 (2.2–4.5)	3.7 (2.4–5.7)	8.7 (6.6–11.6)	7.9 (5.7–10.9)
Approx. once a day	2.1 (1.3–3.5)	2.3 (1.3–4.1)	1.4 (0.9–2.4)	1.8 (1.1–3.2)	1.6 (1.1–2.4)	1.4 (0.9–2.4)	2.2 (1.5–3.2)	2.5 (1.6–3.9)	6.0 (4.6–7.7)	5.8 (4.3–7.7)
Approx. 3–4 times a week	2.1 (1.5–2.9)	2.7 (1.9–3.9)	2.0 (1.5–2.6)	2.6 (1.9–3.7)	1.5 (1.2–2.0)	1.7 (1.3–2.4)	1.7 (1.3–2.3)	2.1 (1.6–2.9)	4.3 (3.6–5.1)	4.0 (3.3–4.9)
Once a week or less	1.5 (1.2–1.8)	1.6 (1.2–2.0)	1.6 (1.3–1.9)	1.8 (1.4–2.2)	1.2 (1.0–1.5)	1.3 (1.1–1.6)	1.4 (1.2–1.7)	1.6 (1.3–1.9)	2.5 (2.2–2.8)	2.2 (1.9–2.5)
Not at all	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Gender										
Female		2.7 (2.1–3.4)		2.6 (2.1–3.2)		2.5 (2.1–3.0)		2.7 (2.2–3.2)		1.4 (1.2–1.5)
Male		1.0		1.0		1.0		1.0		1.0
Parents' education										
Low		0.9 (0.7–1.2)		1.0 (0.8–1.2)		1.1 (0.9–1.3)		0.9 (0.7–1.1)		1.1 (0.9–1.2)
Middle		0.7 (0.6–1.0)		0.8 (0.7–1.1)		1.1 (0.9–1.4)		0.9 (0.7–1.1)		0.9 (0.8–1.0)
High		1.0		1.0		1.0		1,0		1.0
Family structure										
Non-nuclear		1.3 (1.0–1.6)		1.1 (0.9–1.3)		1.2 (1.0–1.4)		1.2 (1.0–1.4)		1.1 (1.0–1.3)
Nuclear		1.0		1.0		1.0		1.0		1.0
Academic achievement										
–6.9		1.8 (1.1–2.8)		1.2 (0.8–1.8)		1.6 (1.1–2.3)		1.5 (1.1–2.2)		1.9 (1.5–2.4)
7.0–7.9		1.6 (1.1–2.2)		1.0 (0.7–1.3)		1.3 (1.0–1.7)		1.4 (1.1–1.8)		1.7 (1.4–2.0)
8.0–8.9		1.2 (0.9–1.7)		0.9 (0.7–1.1)		1.0 (0.8–1.3)		1.1 (0.9–1.4)		1.4 (1.2–1.6)
9.0–10.0		1.0		1.0		1.0		1.0		1.0
Chronic illness										
Yes		2.0 (1.6–2.5)		1.6 (1.3–1.9)		1.5 (1.3–1.8)		1.6 (1.3–1.9)		1.0 (0.9–1.2)
No		1.0		1.0		1.0		1.0		1.0
Nagelkerke R^2	0.021	0.072	0.013	0.053	0.095	0.055	0.014	0.059	0.102	0.114

Odds ratios (OR), and their 95 % confidence intervals (CI), and Nagelkerge R^2 values in crude models and in models adjusted for gender, parents' education, family structure, academic achievement, and chronic illness

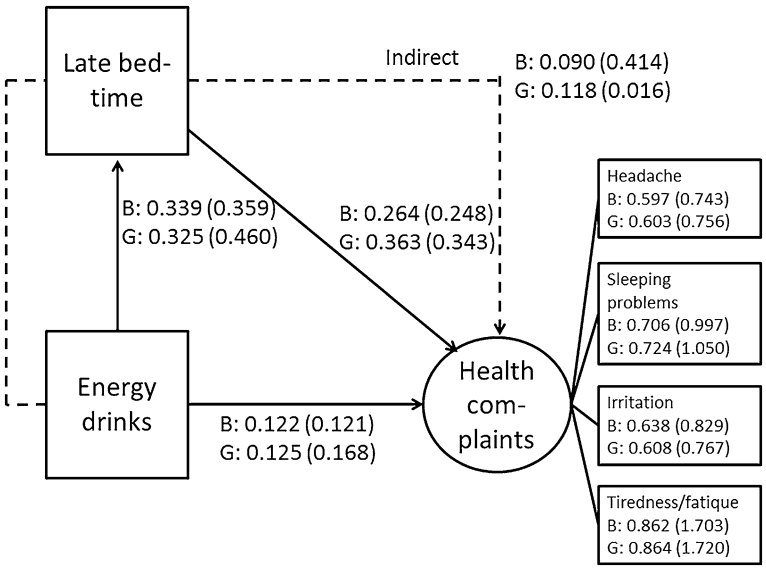

Fig. 1 The structural equation models for the relationships between energy drink use, health complaints and late bedtime in 13-year-old boys (B) and girls (G) in Helsinki metropolitan region, Finland (2011). Loadings for health complaints and standardized coefficients with and standard errors for the direct (*unbroken line*) and indirect (*dash line*) effects

Other energy drinks, such as coffee or cola drinks, which are both sources of caffeine, were not evaluated in this study. In another study on Finnish adolescents, an adjustment was performed for coffee consumption, and the results regarding the association of energy drink consumption with health complaints were similar to the present results (Huhtinen and Rimpelä 2013). The same result was also noted in the study by Kristjansson et al. (2014), which adjusted for the consumption of cola drinks. However, these studies did not address bedtime.

Conclusions

The consumption of energy drinks is related to the increased risk of health complaints and going to bed late. The relationship between energy drink consumption and health complaints is partly mediated through late bedtime. Energy drink consumption creates a risk of a negative cycle of disrupted sleep, increased consumption of energy drinks and an increased number of health complaints. Energy drink consumption, going to bed late, and health complaints form a behavior pattern that is worth considering in schools, home and clinical settings when adolescents complain about headaches, problems with sleeping and corresponding symptoms. Age limits for sale and a ban on the consumption of energy drinks during school hours should be considered.

Further research is needed to clarify whether some groups of adolescents suffer more from the disadvantages of energy drinks and to better understand the causality of the relationships suggested in the paper.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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