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ORIGINAL ARTICLE

Energy drinks in children and adolescents: demographic data and immediate effects

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Abstract

Energy drinks consumption has become increasingly common in the last few years, despite evidence associating these products with vast adverse health effects. This led us to explore the phenomenon of energy drinks consumption in adolescents in the Israeli Arab population of the Nazareth area (Northern Israel), examining their awareness of risks associated with consumption of energy drinks, investigating their immediate effects on the body. Our study revealed that the consumption of energy drinks is very common in adolescents of both sexes, though more common in boys. Of 375 students who filled out the questionnaire, 206 reported that they consumed energy drinks (55%), 91 were male (44.4%), and 115 were female (55.6%). In the experimental stage of this study, we found that energy drinks significantly increased systolic blood pressure in most participants within a brief period of time after drinking.

Conclusion: Given the prevalence of energy drinks consumption and their side effects, it is important to increase awareness of the risks associated with their regular use and to combat this phenomenon through the education system in schools.

What is Known:
- *Energy drinks consumption has become popular and frequent among adolescents across the world.*
- *The immediate effects of energy drinks in children and adolescents are poorly described.*

What is New:
- *Religious and social norms are not a barrier to ED consumption among the varied investigated population.*
- *Our study describes the immediate effect of energy drinks during the first 2 h after consumption, revealing systolic blood pressure to be significantly increased.*

Keywords Energy drinks (EDs) · Consumption · Caffeine · Adolescents · Addiction · Toxicity

Abbreviations

ED Energy drink
EDs Energy drinks
FDA Food and Drug Administration
PDE Phosphodiesterase

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Introduction

In the past few years, the production and marketing of energy drinks (EDs) have increased due to their popularity and there is widespread consumption in diverse populations, especially among children, adolescents, and young adults. Global ED consumption rose by 14% in 2011 according to the latest report from the Zenith International food and drink consultancy [36].

Several studies from the USA and Europe confirm that the prevalence of adolescents reporting ED consumption varies from 20 to 50% [8, 30, 37].

The primary target for the marketing of EDs is young adults and teens, as demonstrated by a recent US survey, which shows that 34% of young adults aged 18–24 and 31% of adolescents aged 12–17 consumed these drinks, as opposed to only 22% of adults aged 25–34 and a mere 3% of people

aged 65 or more. Energy drink marketing focuses on youth-related themes and strategies. The Mintel International Group attributes the popularity of these themes and strategies to their association with teenagers' urge for rebellion, risk taking, and adventure seeking [23].

EDs are beverages that contain large doses of caffeine, sugar, and a variety of other stimulants and substances such as guarana, taurine, or vitamins [12]. Caffeine is considered the main substance that is associated with adverse health consequences among adolescents [27, 31]. Also, the high amounts of sugar contained in these beverages have previously been linked to adverse health and behavioral outcomes in adolescence [13, 27]. The effect of other ingredients contained in EDs on health and behavior of adolescents remains unclear [30]. The FDA does not limit caffeine content in EDs as it does in other soft drinks, since these drinks are categorized as nutritional supplements, thus allowing them to contain high levels of caffeine.

Caffeine is a xanthine, which acts in the body's cells by different mechanisms of action and on a wide range of molecular targets. It intervenes as an antagonist of the adenosine receptors, inhibitor of phosphodiesterase enzymes, sensitizer of calcium liberation channels, and GABA receptor antagonist [7].

Current literature contains many reports of complications resulting from ED consumption, including nausea, vomiting, stomach aches, tachycardia, hypertension, liver damage, renal failure, respiratory abnormalities, restlessness, confusion, seizures, depression, psychotic states, rhabdomyolysis, sleep disturbances, hyperglycemia, diabetes, obesity, hypokalemia, increased cranial pressure, brain edema, arrhythmias, myocardial infarction, cardiac failure, and death [8, 11, 14, 17, 18, 26].

Behavioral correlates were also found, with EDs consumption being associated with more video game use [21], attention deficit hyperactivity disorder symptoms, delinquency, and violent behaviors [19, 20].

Holubcikova et al. [15] showed that adolescents reporting regular ED consumption were at higher risk of several health and behavioral problems such as daily health complaints, poor self-rated health, school dislike, low academic achievement, truancy, fighting, bullying, smoking, and drunkenness.

Many studies on adolescents and young adults showed an association between EDs consumption and heavy drinking patterns [6, 32, 34], increased risk of alcohol and drugs dependence [3], use of illicit drugs [32], and smoking [8, 21]. Mixing of EDs with alcohol increases the duration of action of the caffeine [10].

Serious and even life-threatening side effects of EDs have been described in several case reports. Berger and Alford reported a case of cardiac arrest in a 28-year-old male after drinking 7–8 cans of a caffeinated ED [5]. The victim collapsed, and paramedics found the patient in ventricular fibrillation—he was successfully defibrillated, after which testing did not reveal any coronary disease. Peak et al. described an adult who rapidly developed atrial fibrillation and dilated cardiomyopathy after drinking 575 mg of caffeine a day as an energizing drink [25]. In two prospective studies, Savoca et al. investigated the effects of caffeine consumption on blood pressure, finding a strong link between caffeine consumption and increased systolic and diastolic blood pressure in African-Americans [28, 29]. A case study was published describing acute hepatitis with jaundice and liver function abnormalities in a previously healthy 23-year-old woman, after drinking ten cans of an EDs a day [35]. It was theorized that the niacin content of the EDs was responsible for the hepatitis, although the patient consumed only 300 mg of niacin per day, whereas the lowest known hepatotoxic dose of niacin is 1 g per day.

Because of the growing phenomenon of ED consumption among children and adolescents, and in light of reports of vast numbers of adverse effects and even cases of mortality linked to drinking of these products, this study aimed to investigate:

(a) The prevalence of this phenomenon in adolescents in the city of Nazareth and its province in the northern district of Israel.
(b) The immediate adverse effects of these drinks on the body.

We hypothesized that consumption of EDs is a very prevalent trend among children, adolescents, and young adults, and that this may lead to many adverse effects.

Hopefully, this study can improve our knowledge and evidence based on ED consumption in adolescents, and possibly encourage better education of parents, children, and adolescents on the possible harms hidden in these EDs, and perhaps even prevent the sale of these products to children and adolescents. This study may also serve as a basis for further research into long-term effects of EDs.

Methods

This study was conducted in two consecutive stages.

Stage 1

Aim

Examining the prevalence of ED use among adolescents in the city of Nazareth and its province in the northern district of Israel.

Material

Data were collected from students in four large public senior high schools in the city of Nazareth and surrounding area during March and April 2015. A total of 400 students 16–18 years of age were enrolled in grades 10 through 12. All students in the same school were administered the questionnaire on the same

date; 375 students responded to the questionnaire, the response rate was 93.75%. Non-responders include 25 students who were absent that day or who refused to participate.

The students were administered a two-part survey. The first section included nine socio-demographic questions. The second part comprised 27 questions about ED consumption habits and awareness of adverse effects of these drinks. The questionnaire was compiled based on a literature review of ED use in youth and is modeled after a study by Attila and Cakir [4]. Some questions were changed to be more appropriate to the sampled age group. The questionnaire was translated into Arabic and it was back-translated into English by a different translator to ensure that the meaning of the questions remained the same.

Regarding the first part of the survey, study socio-demographic variables were gender, date of birth, grade, school, address, number of siblings, birth order among siblings, parental occupation, and level of education (low parental education was defined as both parents with at most a high school education and high parental education as at least one parent with academic education).

In the second part of the survey, the respondents were asked if they ever drank EDs, and if so, their age at first consumption, how many cans per day/week, periods of major consumptions (during studies, vacations), if there are other members in household who drink EDs, and about consuming EDs together with friends. They were also asked if EDs are sold in school and if they can get EDs whenever they want. This part of the survey also included questions about other habits, such as drinking alcohol and smoking a hookah (water pipe) and cigarettes. Respondents who drank EDs were asked if they ever needed medical attention due to their side effects.

Knowledge about the main ingredients of EDs, amount of caffeine and negative health effects, such as tachycardia, liver, and kidney damage, respiratory disease, and blood pressure were tested using a series of true and false questions.

Finally, respondents were asked about ED phenomenon prevalence and if they were ever formally taught about EDs and the dangers in consuming them and queried if they would want to receive further information regarding this matter.

Stage two

Aim

Testing immediate effects of ED consumption.

Materials

In this experimental stage, participants aged 16–18 years were recruited randomly based on their answers to the questionnaire administered in stage 1 of the study. The first group consisted of 41 adolescents who drink EDs regularly (defined as consuming at least two cans weekly), and the second group consisted of 40 adolescents that did not ever consume EDs, serving as a control group (Fig. 1).

The sample size was calculated based on detecting a significant difference in systolic blood pressure between the two groups. To have 80% power of detecting this difference (at 5% significance level, two-tailed), we need $N = 42$ in each group. And to have 75% power, we need $N = 37$ in each group.

After parental consent, the students from both groups were invited to the clinic. They were divided into five groups, eight students from each group (ED consumers and non-consumers), the last group (number 5) contained nine students who consumed EDs and eight students who did not.

All five groups were invited on the same day to take part in this experimental stage.

For both groups, we recorded each participant's age, sex, height, and weight; then, heart rate and respiratory rate in minutes and blood pressure using the same Welch Allyn® vital signs monitor were measured by pediatric nurses. Students were asked about their subjective sense of well-being rated on a 1 to 10 scale, where 1 indicates very bad well-being sense and 10 normal.

Afterward, students in the first group (regular ED consumers) received 250 ml of "XL" ED, while students in the second group (who have never consumed EDs) received 250 ml of water.

Vital signs (heart rate, respiratory rate, blood pressure) and subjective sense of well-being were measured at intervals of 15–30 min, 1 h, and 2 h after drinking in the same manner by the same person, and using the same monitor.

Statistical methods

The first stage of the study described the socio-demographic characteristics of the sample. The prevalence of gender, mean age, and number of family members were computed and stratified by category of ED consumption (ED consumers and ED non-consumers). Also, prevalence of alcohol consumption, cigarette, and hookah smoking was described and stratified by category of ED consumption. In addition, awareness of

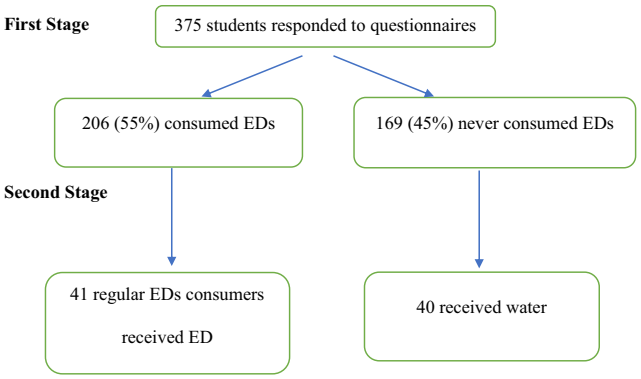

Fig. 1 Study process and subject recruitment in both stages

ED ingredients and their negative effects on health (such tachycardia, blood pressure, liver and kidney function) were also described and compared between the two groups. Differences between ED consumers and non-consumers were tested using Chi-square tests (Table 1).

In the second experimental stage, the sample was stratified in two groups: Students in the first group (regular ED consumers) received "XL" ED, while students in the second group (who have never consumed EDs) received water. Vital signs (heart rate, respiratory rate, systolic, and diastolic pressure) and sense of well-being were measured at four different time points in both groups and were presented as mean and standard deviation. Statistical analyses of the data were made via a two-factor [2 × 4] within-subject repeated measure analysis of variance (ANOVA); means and standard deviations are presented in Table 2. A p value < 0.05 was considered significant. Statistical analyses were performed using IBM SPSS statistics 22.0 for Windows.

Results

Stage 1

In this stage of the study, we enrolled 375 students, 148 males (39.5%) and 227 females (60.5%) who responded to the questionnaire; 206 (55%) students reported ED consumption and 169 (45%) did not. Out of the 206 students who reported drinking these products, 91 (44.4%) were males and 115 (55.6%) were females.

Table 1 shows the results of the survey comparing ED consumers and non-consumers. Data include social and demographic characteristics, EDs and other substance consumption habits, awareness of the ingredients contained in the drinks and their adverse effects.

We found a statistically significant correlation between male gender and ED consumption ($x^2(1) = 4.24$, $p = 0.039$). Out of 148 males who participated in the survey, 61% (91) reported ED consumption and 39% (57) did not. Meanwhile, out of 227 female participants, 50.6% (115) reported ED consumption and (49.4%) 112 had never consumed EDs (Fig. 2).

The second part of the survey included questions regarding consumption habits of EDs and other substances. There was no significant correlation between alcohol use, cigarette or hookah smoking, and the consumption of EDs in the sample population (Table 1).

The second part of the survey was also designed to assess students' awareness of ED ingredients and their effects on health and on the body. The group of participants who did not drink these products was significantly more aware about their ingredients in general (74.5%) when compared to the ED consumer group (62.6%) ($x^2(1) = 6.77$, $p < 0.05$). Non-consumers were also significantly more aware of caffeine as the main active ingredient ($x^2(1) = 8.802$, $p < 0.01$).

In order to test the immediate and the long-term effects of EDs on the body, the study population was asked about their awareness of tachycardia and hypertension as immediate side effects; they also were asked about their effects on liver and kidney function as long-term side effects.

Non-consumers showed more awareness of EDs' immediate effects: Ninety-six percent of them were aware that EDs can cause tachycardia ($x^2(1) = 28.00$, $p < 0.001$) and 93.5% were aware of their effect on raising blood pressure ($x^2(1) = 12.40$, $p < 0.001$).

Non-consumers were also more aware of EDs' long-term side effects: 94% of them were aware that EDs can cause liver function disorder ($x^2(1) = 13.06$, $p < 0.001$) and 93% were aware of their kidney function effect ($x^2(1) = 14.07$, $p < 0.001$).

Stage 2

The first group consisted of 41 adolescents who drink EDs regularly (defined as consuming at least two cans weekly) and

Table 1 Characteristics of the study population based on the survey results by category of energy drinks consumption

Variables	ED consumers *N* (%)	ED non-consumers *N* (%)	Statistical significance (*p* value)
Male	91 (61)	57 (39)	0.039
Female	115 (50.6)	112 (49.4)	0.039
Mean age (years)	16.26	16.25	0.546
Number of Family members	4.39	4.42	0.832
Awareness of general ingredients in EDs	129(62.6)	126(74.5)	0.014
Awareness of main active ingredient (caffeine)	160(77.6)	150(88.7)	0.003
Awareness of tachycardia	157(76.2)	162(95.8)	0.001
Awareness of liver function disturbance	168(81.5)	159(94)	0.001
Awareness of kidney function disturbance	163(79.1)	157(92.9)	0.001
Awareness of hypertension	167(81)	158(93.5)	0.001

Table 2 Summary data of the study on the second stage

	Before		15–30 min after		60 min after		120 min after	
	Water	XL	Water	XL	Water	XL	Water	XL
Hart rate (beats/min)	80.60 (14.4)	79.63 (12.12)	79.90 (10.68)	81 (15.38)	82.22 (11.79)	79.10 (13.34)	83.36 (10.06)	79.10 (12.78)
Respiratory rate (breaths/min)	18.25 (1.30)	18.10 (1.79)	18.65 (1.39)	18.93 (1.62)	20.84 (13.58)	18.93 (1.49)	18.75 (1.08)	18.44 (1.38)
Systolic blood pressure (mmHg)	111.85 (11.29)	119.10* (9.98)	109.78 (10.47)	121.85** (12.51)	105.84 (19.59)	121.59** (12.47)	105.81 (19.62)	117.83** (13.30)
Diastolic blood pressure (mmHg)	65.28 (9.03)	69.12 (14.35)	64.08 (9.86)	70.39 (10.38)	62.86 (9.41)	71.98 (12.10)	62.58 (8.17)	69.95 (8.57)
Sense of well-being	6.80 (2.78)	7.54 (1.82)	8.53 (2.55)	7.71 (1.68)	8.81 (2.44)	7.54 (2.00)	9.17 (1.08)	8.41 (1.88)

Data are presented as mean (±standard deviation)

*$p < 0.05$ between group difference at same time point

**$p < 0.001$ between group difference at same time point

the second group of about 40 adolescents that did not ever consume EDs, serving as a control group.

Vital signs (heart rate, respiratory rate, blood pressure) and subjective sense of well-being were measured at intervals of 15–30 min, 1 h, and 2 h after drinking in both groups (regular ED consumers and non-consumers) as described.

Table 2 summarizes the results of different measures (heart rate, respiratory rate, blood pressure, and subjective sense of well-being) at four different time points (before drinking EDs, at 15–30 min, 1 h, and 2 h after drinking).

Statistical analysis revealed that regular ED consumers had higher mean systolic and diastolic blood pressure measured at the four time points. Systolic blood pressure was found to be significantly affected by ED consumption at baseline (before drinking) ($p < 0.05$), at 15–30 min, 1 h, and 2 h after drinking ($p < 0.001$).

Heart rate, respiratory rate, diastolic blood pressure, and subjective sense of well-being were not significantly affected at any time point in both groups.

Discussion

Our study consisted of two stages; in the first stage, we investigated the prevalence of ED consumption in adolescents aged 16–18 years, explored their awareness of adverse effects associated with these drinks, and tried to find a correlation between alcohol consumption, smoking cigarettes or hookah, and ED consumption. This was achieved through a questionnaire survey of high school students, grades 10–12, in four schools in the Nazareth area.

Statistical analysis of the survey results revealed ED consumption to be quite common among adolescents in the Israeli Arab population of Nazareth area (northern Israel); 206 (55%) out of the 375 participants reported drinking EDs, while 169 (45%) did not. Average age was 16.2 years, similar in consumers and non-consumers.

Stratification by sex revealed that 61% of males (91 of 148) consumed EDs. On the other hand, only 50.6% of females (115 of 227) consumed these drinks. It seems that this phenomenon was prevalent in both sexes, but more in males. Several studies from the USA and Europe confirm that the prevalence of adolescents reporting ED consumption varies from 20 to 50% [8, 30, 37]. A study from Italy conducted by Gallimberti et al. [8] during the 2011–2012 school year in the Province of Rovigo in the Veneto Region (northeastern Italy), involving a sample of 916 students, showed that the use of energy drinks increased significantly with age, from 17.8% among sixth graders to 56.2% among eighth graders. Comparing these data with our study, we noticed that although the students included in our study were older (tenth to twelfth graders), the percentage of students reported to be ED consumers (55%) was quite similar to those in eighth grades described in the Italian study (56.2%).

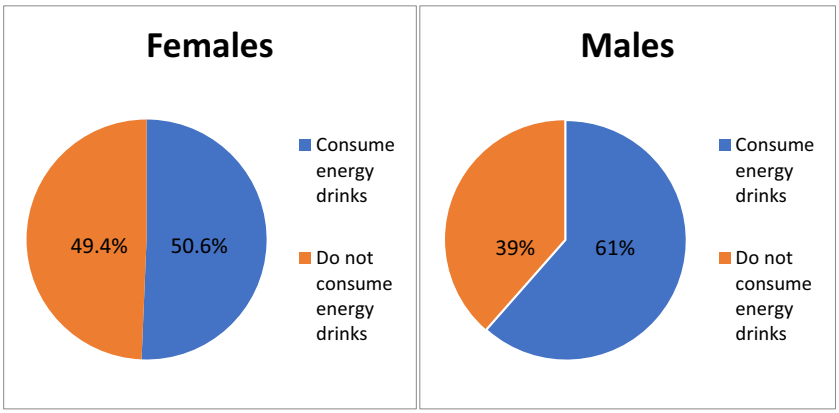

Fig. 2 Proportion of adolescents declaring ED consumption presented by gender (in percentage)

Taking into consideration the fact that the majority of our study population was Muslim, another indicative and representative study to compare with was a multi-stage study stratified sampling procedure carried out to select 1061 school children aged 12–19 years, from Jeddah city, Saudi Arabia (a Muslim population). A short self-reported questionnaire showed that 45% of participants drank EDs (71.3% males and 35.9% females) [24].

Although this study was conducted in an Arab population, a relatively conservative population, the phenomenon of ED consumption proves to be very common, surprisingly even in females, in which cigarette smoking and drinking are quite uncommon. This indicates that religious and social norms are not a barrier to ED consumption among Arab teens.

Several studies from the USA and Europe have demonstrated a clear association between EDs and alcohol consumption [6, 8, 32, 34]. However, our study revealed no correlation between alcohol and ED consumption. A reasonable explanation is that the majority of the study population was Muslim, where drinking alcohol is generally forbidden, explaining the relatively low rates of alcohol consumption among the survey participants.

A correlation between both cigarette or hookah smoking and ED consumption was demonstrated in several studies [2, 8, 21]. Akl et al. [2] showed that the prevalence of hookah smoking appears to be alarmingly high among school and university students in Middle Eastern countries (our region). Nevertheless, our study surprisingly found no correlation between smoking, of both cigarettes or hookah, and ED consumption. Since both phenomena seem to be very widespread in our population, further research with larger samples is needed to verify the correlation between them.

Awareness regarding ingredients contained in EDs, specifically caffeine, was greater in students who did not drink them. That was also concluded by Gallimberti et al., showing that awareness among students of the potential damage caused by energy drinks was found to have a protective role, reducing the likelihood of drinking them [8]. Similarly, ED non-consumers were more familiar with their side effects, such as increased blood pressure, tachycardia, and disturbances in liver and kidney function. The lower prevalence of ED consumption in students with greater awareness of their ingredients and adverse effects promotes the possibility of reducing the use of EDs among adolescents by increasing awareness of their effects. Perhaps this can be achieved by encouraging parents and schools to educate students of these adverse effects.

The second, experimental, stage of the study investigated the immediate effects of ED consumption. Participants were adolescents ages 16–18 years, divided into two groups based on ED consumption; the first group consisted of students who did not consume EDs, while the second group included regular users of these products. A total of 81 students participated—40 in the control group, who drank 250 ml of water, and 41 students who regularly drank EDs and were given a 250-ml can of XL drink within the experiment.

Measurements and analysis of blood pressure revealed that systolic blood pressure in the regular ED consumers was significantly higher than in the control group in the four time points of measurements: at baseline, and 15–30 min, 1 h, and 2 h after consumption. This effect of EDs on blood pressure in regular users may adversely affect the health of these adolescents over the long term with the serious complications known to arise from hypertension, including increased left ventricular mass (LVM), greater carotid intima-media thickness (cIMT) [16], stiffer arteries [33], reduced endothelial function [9], and renal [22] as well as neurocognitive impairments [1].

The association of caffeinated beverages with blood pressure in adolescents has been demonstrated in two prospective studies conducted by Savoca et al. [28, 29], who investigated the effects of caffeine consumption on blood pressure, finding a strong correlation between caffeine consumption and increased systolic and diastolic blood pressure in African-Americans.

We found no significant difference at any time point between the groups on the other measures, including heart rate, respiratory rate, diastolic blood pressure, and subjective sense of well-being. However, this does not rule out any long-term effects on these measures or effects that may appear by consuming higher doses of EDs. Further studies are necessary in order to evaluate and monitor the long-term effects of EDs on the body.

Study limitations

First stage: the sample size of students who filled out the survey was somewhat small and may not be entirely representative of the Arab population or inhabitants of the Nazareth area. The sample was also not necessarily representative in terms of geographic distribution or cultural demographics. In addition, data were cross-sectional, and this limits the ability to draw causal inferences.

Second stage: it was not possible to perform this study with a blinded placebo control group.

Another limitation was that data about other caffeine beverages such as coffee, tea, and other stimulants (such as attention deficit hyperactivity disorder medications) were not collected.

Conclusion

This study demonstrated that ED consumption is highly prevalent in Arab Israeli adolescents in the Nazareth area (northern Israel), especially among males. We found an inverse relationship between awareness of the ED ingredients, their harmful effects, and their consumption. Our findings provide evidence about the importance of preventive actions aimed at reducing adolescents' consumption of EDs. We suggest that both parents and students need to be educated about the risks of ED consumption and that access to ED should be restricted.

In the second stage of the study, we demonstrated the immediate effect of EDs on raising systolic blood pressure. This may also be useful information in efforts to curb the widespread consumption of EDs.

Authors' Contributions Bshara Mansour drafted the initial manuscript, revised the analyses, and revised the final manuscript as submitted. Nael Elias carried out the initial analyses, revised the manuscript, and approved the final manuscript as submitted. Wesam Amarah and Elias Nasralla finalized data collection forms and supervised the data collection.

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Compliance with ethical standards

Ethical standard The study was approved by the Ethics Committee of the Saint Vincent De Paul Hospital and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Parents of respondents were informed about the study via the school administration and the investigators; they gave their informed consent prior to inclusion of their children in the study and could opt out if they disagreed with their child's participation. Participation in the study was fully voluntary and anonymous with no explicit incentives provided for participation.

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

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