Energy drinks in children and adolescents

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# Abstract

In the last few years, there is a growing impression of increasingly prevalent consumption of energy drinks among children and adolescents, despite the collective assumption of the population that such products are harmful to one’s health. This led us to explore, with this study, the phenomenon of energy drink consumption in adolescents in the Israeli Arab population, and examine their awareness of risks associated with consumption of energy drinks, while also investigating the immediate effects of these energy drinks on the body. This study was conducted in two parts; the first – a statistical analysis of a questionnaire survey distributed to about 400 high school students in the city of Nazareth and the surrounding area. The second, more experimental part, explored the immediate effects of energy drinks on consumers, compared to a control group of students drinking similar quantities of water instead. Our study revealed that the consumption of energy drinks is very common in adolescents of both sexes, though more common in boys. Out of 375 students who filled out the questionnaire, 206 reported that they consumed energy drinks (55%), and 169 (45%) responded that they did not consume energy drinks whatsoever. Out of the 206 students who consumed energy drinks, 91 where male (44.4%) and 115 were female (55.6%). A total of 148 males completed the questionnaire, 91 of which consumed energy drinks (61%), and 57 did not. Of female students, on the other hand, 227 completed the questionnaire, of which 115 (506%) consumed energy drinks regularly, and 112 (49.4%) did not consume any energy drinks. In the experimental portion of this study, we found that energy drinks significantly increased blood pressure in most participants, a brief period of time after drinking. *Conclusion*: Given the prevalence of energy drink consumption, and the side effects of these products, it is important to increase awareness of the risks associated with regular use of energy drinks, and to combat this phenomenon through the education system in schools.

## Key terms:

* Energy drinks
* Caffeine
* Adolescents
* Addiction
* Toxicity

## Abbreviations:

<Alphabetical list>

## What is known:

## What is new:

# Introduction

In the past few years, the production and marketing of energy drinks has increased due to their popularity and widespread consumption in diverse populations, especially among children, adolescents, and young adults. Previous surveys have shown that 30%-50% of adolescents and young adults consume these drinks regularly [1, 2]. One proposed explanation is that heavy marketing towards young consumers, together with their general tendency towards risk-seeking behavior, put young people at higher risk for overconsumption.

Caffeine is the main active ingredient, present in large quantities in most energy drinks [3–5], which often contain other substances designed to increase energy, including the amino acid taurine, guarana (a caffeine containing plant), B-group vitamins, and carbohydrates [6, 7]. The FDA does not limit caffeine content in energy drinks 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, a substance of the methylxanthine class, acts on the body through multiple mechanisms, such as phosphodiesterase (PDE) inhibition, adenosine receptor antagonism, and release of catecholamines [8]. Current literature contains many reports of complications resulting from energy drink consumption, including nausea, vomiting, stomach aches, tachycardia, hypertension, liver damage, renal failure, respiratory abnormalities, restlessness, confusion, seizures, psychotic states, rhabdomyolysis, sleep disturbances, hyperglycemia, obesity, hypokalemia, increased cranial pressure, brain edema, arrhythmias, myocardial infarction, cardiac failure, and death [9–18]. Another dangerous phenomenon among adolescents and adults is the mixing of energy drinks with alcohol, which increases the duration of action of the caffeine [19].

Recently, Berger and Alford reported a case of cardiac arrest in a 28 year old male, after drinking 7-8 cans of a caffeinated energy drink [20]. 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 that rapidly developed atrial fibrillation and dilated cardiomyopathy after drinking 575 mg of caffeine a day, as an energizing drink [21]. 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 [22, 23]. Recently, a case study was published describing acute hepatitis with jaundice and liver function abnormalities in a previously healthy 23 year old woman, after drinking 10 cans of an energy drink a day [24]. It was theorized that niacin content of the energy drink 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 gram per day. In November of 2012, the FDA released a warning against consumption of energy drinks after 18 reports of fatalities linked to use of highly-caffeinated energy drinks [25].

## Study objectives:

Given the lack of information and research regarding the increasingly prevalent phenomenon of energy drink 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, the objectives of this study were to investigate:

1. The prevalence of this phenomenon in children and adolescents in the Nazareth area
2. Research the immediate adverse effects of these drinks

## Hypothesis:

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

## Significance of this study

Hopefully this study can improve our knowledge and evidence base on energy drink consumption in adolescents, and possibly encourage better education of parents, children, and adolescents on the possible harms hidden in these energy drinks, 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 energy drinks.

# Methods

This study was conducted in two parts:

## Part one:

Examining the prevalence of energy drink use among adolescents in Nazareth

### Study population:

Students of from grades 10-12 in Nazareth high schools – a total of about 2,105 students. A questionnaire survey was distributed to a representative sample (about 400 students) of this group, which includes demographic information, social conditions, name of school attended, exposure to energy drinks, exposure to cigarette and hookah smoking, and alcohol use.

### Variables:

Variables are detailed in the questionnaire (see supplement), all of which were collected from the questionnaire responses.

### Procedure:

The first part was accomplished using an anonymous survey of adolescents, with questions including demographic information, energy drink consumption habits, and awareness of adverse effects of these drinks. The questionnaire was distributed to 375 students grades 10-12 in four high schools in the city and surrounding area of Nazareth.

### Statistical methods

Quantitative variables (e.g. age, number of family members) and standard deviations are presented in tables, and analyzed using two-sample t-test. Nominal and other categorical variables are presented as percentages. Comparison of frequencies was analyzed using Pearson’s chi-squared test. Statistical significance was considered at p<0.05. Analysis was performed using SPSS software.

## Part two:

Testing immediate effects of energy drink consumption.

### Study population:

Children and adolescents ages 12-18 years from the Nazereth area. The first group consisting of about 50 children who drink energy drinks regularly, and the second group of about 50 children that do not consume energy drinks serving as a control group.

### Variables:

Measures taken before and after drinking an energy drink or water, including: blood pressure, heart rate, and respiratory rate.

### Procedure:

Participants in the study included two groups of students ages 12-18; the first group consisted of students that regularly consume energy drinks, and the second of students who did not consume such drinks at all. Students who regularly drank energy drinks were invited to one appointment where they are asked to drink one can of energy drink. Measurements were taken of height, weight, heart rate, blood pressure, and respiratory rate, and repeated measurements of heart rate, blood pressure, and respiratory rate were taken 30, 60, and 120 minutes after drinking.

The control group underwent the same procedure, drinking the same quantity of water instead of the energy drink.

# Results

## Part one:

In the first part of the study, 375 questionnaires were distributed to students in four high schools in the city and surrounding area of Nazareth, including students grades 10-12.

The questionnaire consisted of demographic questions about the participants in addition to questions about energy drink consumption and awareness of the ingredients contained in the drinks and adverse effects associated with them.

Out of 375 students (148 male, 227 female) who responded to the questionnaire (of which 206 (55%) students reported use of energy drinks and 169 (45%) did not.

Out of the 206 students who reported drinking these products, 91 (44.4%) were male, and 115 (55.6%) were female.

A total of 148 males participated in the survey, 91 of which (61%) consumed energy drinks. Meanwhile, 227 females participated, of which 115 (50.6%) were users (see Figure 1).

Figure 1: <INSERT CAPTION>

We looked for associations between energy drink use and various other factors, using chi-squared and t-testing, with a p-value less than 0.05 considered significant.

We found a statistically significant association between male sex and energy drink use (p=0.039, pcs – 4.24).

When examining age of respondents, it was found that energy drink consumers had an average age of 16.26, ranged 16-19 years, while non-consumers had a mean age of 16.25 (ranged 16-18 years), revealing no statistically significant difference between the two groups (P=0.55).

Table 1: <INSERT CAPTION>

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | Consume energy drinks  n (%) | Do not consume energy drinks  n (%) | Statistical Significance  (p-value) |
| Male | 91 (61) | 57 (39) | 0.039 |
| Female | 115 (50.6) | 112 (49.4) | 0.039 |
| Mean age | 16.27 | 16.25 | 0.546 |

The questionnaire included a number of questions regarding other lifestyle habits that may accompany energy drink consumption. There was no significant association between alcohol use and the consumption of energy drinks in the survey respondents, P=0.98, PCS 0.44. Similarly, there was no significant difference in cigarette smoking (P=.001, P=0.98) or hookah smoking (p=0.538 , pcs=1.238) in energy drink consumers and those who did not drink energy drinks

Table 2: <INSERT CAPTION>

|  |  |  |  |
| --- | --- | --- | --- |
| Variables | Consume energy drinks  n (%) | Do not consume energy drinks  n (%) | Statistical Significance  (p-value) |
| Alcohol use | 17(8.2) | 1(14.2) | 0.976 |
| Cigarette smoking | 30(14.6) | 1(14.2) | 0.980 |
| Hookah smoking | 70(33.9) | 1(14.2) | 0.538 |

The second part of the survey was designed to assess students’ awareness of health effects of energy drinks on the body.

Students were asked whether they know of any effects energy drinks on a person’s health; 40.2% replied that they had no knowledge of any health effects of energy drinks. There was no correlation between awareness of health effects and use of energy drinks (P=0.533, pcs = 0.388).

Next, we checked whether students who consumed energy drinks had ever received any explanation or information from their physician or from any other authority, regarding cessation of energy drink consumption. In the survey, 57% energy drink users reported receiving instruction encouraging them to stop energy drink consumption. No association was found between receiving such instruction and energy drink consumption (pcs=2.269, p=0.132).

However, the group of participants who did not drink these products, were more knowledgeable about their ingredients (pcs=6.77, p=0.014). Evaluation of students’ awareness of caffeine being the main active ingredient revealed a strong correlation between knowledge of the main ingredient and consumption – non-consumers were more aware of the energy drink’s content (pcs = 8.802, p = 0.003).

Another question in the survey inquired about the possible effect of tachycardia resulting from energy drinks. There was a significant association between awareness of this effect and energy drink consumption. Ninety-five percent of students who did not consume energy drinks were aware that the drink can cause tachycardia (pcs=28.00, p<0.001).

In order to test students’ awareness of long term effects of energy drinks, they were asked if they knew of an effect energy drinks had on liver function. Analysis revealed significant association between consumption and awareness: 81.5% of energy drink consumers were aware of this effect, while 94% of non-consumers were aware of this effect (pcs=13.06, P<0.001). Similarly, there was an association between awareness of adverse effects on kidney function and energy drink consumption. In energy drink consumers, 79% reported being familiar with these effects, compared to 93% non-consumers who know of these possible consequences (pcs 14.07, P<0.001). Another important question in the survey inquired about any knowledge the students had regarding effects of energy drinks on blood pressure. Here too, non-consumers showed greater awareness (93.5%) compared to regular users of energy drinks (81%).

Table 3: <INSERT CAPTION>

|  |  |  |  |
| --- | --- | --- | --- |
| Question | Energy drink consumers  n (%) | Energy drink non-consumers  n (%) | P-value |
| Awareness of health effects of energy drinks | 83(40.2) | 2(28.5) | 0.533 |
| Received instruction to stop consuming energy drinks | 118(57.2) | 2(28.5) | 0.132 |
| Awareness of ingredients in energy drinks | 129(62.6) | 126(74.5) | 0.014 |
| Awareness of main active ingredient (caffeine) | 160(77.6) | 150(89.2) | 0.003 |
| Do energy drinks cause tachycardia? | 157(76.2) | 162(95.8) | 0.001 |
| Do energy drinks cause liver function test abnormalities? | 168(81.5) | 159(94) | 0.001 |
| Do energy drinks affect kidney function? | 163(79.1) | 157(93.6) | 0.001 |
| Do energy drinks raise blood pressure? | 167(81) | 158(93.5) | 0.001 |

## Part two:

The second part of our study evaluated two groups of students, ages 12-18 years; one control group of students who do not drink energy drinks, and a second group of regular energy drink consumers.

After parent consent, the students were invited to the clinic where each student in the first group received 250 ml of water, and in the second group received 250 ml of “XL” energy drink.

For both groups, we recorded each participants’ age, sex, height and weight, and measured blood pressure, heart rate, and subjective sense of wellbeing before drinking their respective drinks, and at intervals of 15-30 minutes, one hour, and two hours after drinking.

This part of the study included 81 students – 40 of which received water, and 41 received XL energy drink. Age of participants ranged from 12-18 years, 42.7% of which were 15 years old. Results are summarized in the following table, including age, height, weight, and study measurements:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Drink | Number of participants | Mean | Standard deviation |
| Age | Water | 40 | 13.88 | 1.38 |
| XL Drink | 41 | 15.02 | 1.06 |
| Height | Water | 40 | 158.80 | 10.49 |
| XL Drink | 41 | 163.90 | 19.03 |
| Weight | Water | 40 | 55.75 | 15.72 |
| XL Drink | 41 | 60.15 | 11.43 |
| Base systolic blood pressure | Water | 40 | 111.85 | 11.29 |
| XL Drink | 41 | 119.10 | 9.98 |
| Base diastolic blood pressure | Water | 40 | 65.28 | 9.03 |
| XL Drink | 41 | 69.12 | 14.35 |
| Heart rate | Water | 40 | 80.60 | 14.40 |
| XL Drink | 41 | 79.63 | 12.12 |
| Respiratory rate | Water | 40 | 18.25 | 1.30 |
| XL Drink | 41 | 18.10 | 1.79 |
| Systolic blood pressure, 15-30 minutes | Water | 40 | 109.78 | 10.47 |
| XL Drink | 41 | 121.85 | 12.51 |
| Diastolic blood pressure, 15-30 minutes | Water | 40 | 64.08 | 9.86 |
| XL Drink | 41 | 70.39 | 10.38 |
| Subjective sense of wellbeing | Water | 40 | 6.80 | 2.78 |
| XL Drink | 41 | 7.54 | 1.82 |
| Heart rate 15-30 minutes | Water | 40 | 79.90 | 10.68 |
| XL Drink | 41 | 81.00 | 15.38 |
| Respiratory rate 15-30 minutes | Water | 40 | 18.65 | 1.39 |
| XL Drink | 41 | 18.93 | 1.62 |
| Subjective sense of wellbeing 15-30 minutes | Water | 40 | 8.53 | 2.55 |
| XL Drink | 41 | 7.71 | 1.68 |
| Systolic blood pressure after 1 hour | Water | 37 | 105.84 | 19.59 |
| XL Drink | 41 | 121.59 | 12.47 |
| Diastolic blood pressure after 1 hour | Water | 37 | 62.86 | 9.41 |
| XL Drink | 41 | 71.98 | 12.10 |
| Heart rate after 1 hour | Water | 37 | 82.22 | 11.79 |
| XL Drink | 41 | 79.10 | 13.34 |
| Respiratory rate after 1 hour | Water | 37 | 20.84 | 13.58 |
| XL Drink | 41 | 18.93 | 1.49 |
| Subjective sense of wellbeing after 1 hour | Water | 37 | 8.81 | 2.44 |
| XL Drink | 41 | 7.54 | 2.00 |
| Systolic blood pressure after 2 hours | Water | 37 | 105.81 | 19.62 |
| XL Drink | 41 | 117.83 | 13.30 |
| Diastolic blood pressure after 2 hours | Water | 36 | 62.58 | 8.17 |
| XL Drink | 41 | 69.95 | 8.57 |
| heart rate after 2 hours | Water | 36 | 83.36 | 10.06 |
| XL Drink | 41 | 79.10 | 12.78 |
| Respiratory rate after 2 hours | Water | 36 | 18.75 | 1.08 |
| XL Drink | 41 | 18.44 | 1.38 |
| Subjective sense of wellbeing after two hours | Water | 36 | 9.17 | 1.08 |
| XL Drink | 41 | 8.41 | 1.88 |

Statistical analysis revealed the following:

Even at baseline, before drinking the energy drink, the regular energy drink consumers had higher average systolic blood pressure than the non-consumer group, p=0.03. There was no difference in diastolic blood pressure between the two groups before drinking, p=0.154. At 15-30 minutes after drinking, the group given the XL energy drink demonstrated increased average systolic blood pressure compared to the group given water (p<0.001). However, there was no difference in diastolic blood pressure at this point (p=0.06). Comparison of systolic and diastolic blood pressure one hour and two hours after drinking, revealed an increase in blood pressure in the group receiving XL compared to the control group who drank water (p<0.001). There were no significant differences in other measures including heart rate, respiratory rate, and general wellbeing.

# Discussion

Our study consisted of two parts:

In the first part, we investigated the prevalence of energy drink consumption in adolescents aged 15-18 years, and explored their awareness of adverse effects associated with these drinks. This was achieved through a questionnaire survey of high school students grades 10-12, in four school in the Nazareth area.

Statistical analysis of the survey results revealed that 206 out of the 375 participants reported drinking energy drinks regularly, while 169 did not. It is apparent that energy drink consumption is quite common - 55% of students were regular consumers of these drinks.

Stratification by sex revealed that 61% of males (91 out of 148) consumed energy drinks. On the other hand, only 50% of females (115 of 227) consumed these drinks. It seems that this phenomenon was prevalent in both sexes, but more so in males.

Although this study was carried out in an Arab population, which is generally quite conservative, it is apparent that energy drink consumption is very widespread, 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 energy drink consumption among Arab teens.

Average age was 16.2 years, similar in users and non-users of energy drinks.

Smoking, both of cigarettes or hookah, were not correlated with energy drink consumption – indicating that this is an independent phenomenon, that is not associated with other habits such as with drinking coffee together with cigarettes.

Similarly, alcohol was not correlated with energy drink consumption. It is important to note that the majority of the study population were Muslim, where alcohol use is generally forbidden, explaining the relatively low rates of alcohol consumption in the survey participants.

Students’ awareness regarding ingredients contained in energy drinks, specifically caffeine, was greater in students who did not drink them. Similarly, non-users of energy drinks were more familiar with side effects associated with energy drinks, such as increased blood pressure, tachycardia, and disturbances in liver and kidney function. The lower prevalence of energy drink consumption in students with greater awareness of the ingredients and adverse effects of energy drinks, promotes the possibility of reducing the use of energy drinks among adolescents by increasing awareness of its effects. This can be achieved perhaps by encouraging parents and schools to educate students of these adverse effects.

The second, experimental, part of the study, investigated the immediate effects of energy drink consumption. Participants were adolescents ages 12-18 years, divided into two groups based on energy drink usage; the first group consisted students who did not consume energy drinks, 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 energy drinks and were given a 250 ml can of XL drink within the experiment.

Measurements and analysis of blood pressure revealed that the base systolic blood pressure in the regular consumers of energy drinks was significantly higher than the control group. Shortly after drinking the energy drink, we found significantly increased systolic and diastolic blood pressure compared to participants who drank water. Our study revealed a short and long-term effect of energy drinks in regular users, which may adversely affect the health of these adolescents over the long term with the serious complications known to arise from hypertension, including cerebrovascular events, kidney injury, etc.

We found no significant difference between the groups in other measures, including heart rate, respiratory rate, and subjective sense of wellbeing after drinking XL energy drink compared to the control group. However, this does not rule out any long-term effects on these measures. Similarly, we cannot rule out effects that present with use at higher doses, as well as other adverse effects not studied. Further research is necessary with long term surveillance and monitoring of health effects over years of regular consumption of energy drinks.

## Study limitations

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

# Conclusion:

In this study, we demonstrated that energy drink consumption is highly prevalent in Arab adolescents in the Nazareth area – more than 50% of adolescents of grades 10-12 drink these products, especially among males. Similarly, we found an inverse relationship between awareness of the ingredients in energy drinks and harmful effects, and the consumption of these drinks. This is important – it is potentially useful as a tool to reduce consumption of these drinks through increased awareness and education.

In the second part of the study, we demonstrated the immediate effects of energy drinks, as manifested by increases in systolic blood pressure. This may also be useful information in efforts to curb the widespread consumption of energy drinks.

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# Questionnaire:

Date of birth:

Male/female:

Number of siblings:

Birth order among siblings:

Parents’ occupation:

Parents’ education

Grade:

School:

Address:

Do you drink energy drinks?

Yes (continue with following questions)

No (skip to question 19)

1. At what age were you first exposed to energy drinks?
2. Do you consume energy drinks at least twice per week? Yes / No
3. Do you drink a can a day of energy drinks? Yes / No
4. Do you drink two or more cans of energy drinks a day? Yes / No
5. Are there other members in your household who drink energy drinks? Yes / No
6. Do you consume energy drinks together with friends? Yes / No
7. Do you drink energy drinks at school? Yes / No
8. Do you drink alcohol? Yes / No
9. Do you mix energy drinks with alcohol? Yes / No
10. Do you smoke cigarettes? Yes / No
11. Do you smoke hookah? Yes / No
12. What part of the year do you consume more energy drinks? 1 - During studies 2 - During vacations
13. Are energy drinks sold on school grounds? Yes / No
14. Have you ever felt that drinking energy drinks has affected your health? Yes / No
15. Have you ever been to the emergency room because of energy drink consumption? Yes / No
16. Do you think you could quit drinking energy drinks if/when you wanted to? Yes / No
17. Do you think there is a connection between energy drinks and medical problems? Yes / No
18. Have you ever received any instruction from your physician or another person, to stop drinking energy drinks? Yes / No
19. Do you think this phenomenon is common in adolescents? Yes / No
20. Do you refrain from drinking energy drinks because it may be harmful your health? Yes / No
21. Are you aware of what ingredients are contained in energy drinks? Yes / No
22. Are you aware that energy drinks contain caffeine? Yes / No
23. Do you know the health effects of energy drinks? Yes / No
24. Does drinking large amounts of energy drinks cause tachycardia? Yes / No
25. Does drinking large amounts of energy drinks cause liver function abnormalities? Yes / No
26. Does drinking large amounts of energy drinks cause kidney function abnormalities? Yes / No
27. Does drinking large amounts of energy drinks raise blood pressure? Yes / No

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