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REVIEW PAPER

Energy drink consumption as an indicator of an anti-health lifestyle*

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Abstract

A proper, healthy lifestyle involves engaging in health-promoting behaviors, such as not using psychoactive substances. In recent years, the consumption of energy drinks has been rising. Energy drinks are usually carbonated soft drinks to which substances that affect the functioning of the body are added. Aim of the study: The aim of the present study is to uncover the possible adverse health effects associated with the consumption of energy drinks, as well as to systematize knowledge regarding this issue, while adding to it the findings of recent studies. Method: A review of epidemiological studies showing adverse health effects of energy drink consumption was conducted. It used the bibliometrics covering the time period between 2020 and 2024. The analysis of bibliographic data was carried out based on the appropriate keyword subject classification criterion. Results: Caffeine is a compound from the purine alkaloid group. As the main active ingredient of energy drinks, it is primarily responsible for the adverse effects of their consumption. It is noted that people who regularly consume caffeine-rich energy drinks suffer from alarming symptoms such as palpitations, increased blood pressure, feelings of restlessness, chest pain, shallow and accelerated breathing, dizziness and headache, gastrointestinal incidents or erectile dysfunction in males. In addition, acute caffeine intoxication is known to manifest as tachycardia and cardiac arrhythmia, atrial fibrillation, vomiting, sleep disturbances, and exacerbation of existing mental illness. Conclusions: There has been an alarming increase in the consumption of energy drinks observed in young people, which may cause them to develop chronic illnesses. It is necessary to conduct detailed research which would take into account the wide range of effects of energy drinks on the human body, paying special attention to minors.

Keywords: energy drinks, caffeine, health, hazards, side effects

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INTRODUCTION

Lifestyle is a concept raised in research and subject to analysis of many scientific fields, such as medicine, health promotion, sociology, psychology, public health. Scientists believe that the concept of lifestyle (one's way of life) is both difficult to define and hard to measure and assess in studies on the behavior of individual people. In the most general terms, it can be assumed that a lifestyle is a specific way in which an individual lives, the foundation of which is formed by certain behavioral patterns, resulting from the interaction of one's personal characteristics, social conditions, and the socioeconomic and environmental circumstances in which they live (Soroka et al. 2023). Among the health-related behaviors, which are formed throughout one's life, we can distinguish pro-health behaviors, which improve one's well-being, and anti-health behaviors (drinking alcohol, smoking cigarettes or using other psychoactive substances). In view of the above, lifestyle is of great importance in maintaining one's health.

There has been a growing concern about the increased consumption of energy drinks (ED), containing moderate to high concentrations of caffeine, as well as taurine, herbal supplements and sugar or sweeteners, which has been an issue especially among adolescents and young adults. The global supply of ED to consumers is highly varied. In the United States, the domestic ED market was worth $11 billion in 2018 (Kraak et al. 2020), while in Poland, consumers spent 1.285 billion PLN on EDs in 2015 (Kowalski 2017).

Most of the health damage caused by ED consumption is due to excessive caffeine. Its negative health effects have been reported, including such symptoms as headaches, hallucinations, muscle tremors, anxiety, insomnia, restlessness, epileptic seizures, depression, ischaemic stroke, adverse effects on the cardiovascular system, the gastrointestinal tract, the kidneys, and the teeth, obesity and type II diabetes, cancer and caffeine toxicity (Ariffin et al. 2022).

ED, commonly known as energy drinks or energizers, are drinks manufactured to generate mental and physical stimulation. ED are categorised as foodstuffs for particular nutritional uses. EDs are non-alcoholic products containing ingredients such as caffeine, amino acids (taurine), plant stimulants (guarana), herbs (ginkgo biloba), ginseng, glucuronolactone, inositol and L-carnitine and vitamins (niacin), among others (Higgins et al. 2018, Żukiewicz-Sobczak et al. 2018). Data on the presence and quantity of selected ED ingredients in final products are given in Table 1.

ED ingredient concentrations vary widely, and manufacturers often do not disclose the exact amounts of each ingredient. ED mainly contain caffeine, which may be combined with other ingredients such as sweeteners (natural or artificial), glucuronolactone, amino acids (mainly taurine, sometimes L-carnitine), B vitamins and herbal supplements such as ginseng

Table 1

Prevalence and quantity of ED ingredients (both disclosed and undisclosed) present in the best selling energy drinks (modified), Jagim et al. 2023

Ingredient	Overall prevalence (%)	Prevalence in undisclosed quantity (%)	Prevalence in listed quantity (%)	Mean ± SD listed quantity
Caffeine (mg)	100	0	100	174±81
Taurine	37.3	37.3	0	N/A
Ginseng	30.7	30.7	0	N/A
Guarana	25.3	25.3	0	N/A
Carnitine	16.0	16.0	0	N/A
Choline (mg)	2.7	0	2.7	267±330
Sugars (g)	45.3	0	45.3	19.9±18.2
Tyrosine	22.7	22.7	0	N/A
L-Theanine	17.3	17.3	0	N/A
Niacin (% of DV)	66.7	0	66.7	121±70

or gingko. Additional caffeine may be found in other compounds present on ED labels, such as guarana, yerba mate or kola nuts. On average, the caffeine content of ED ranges from 75 to 240 mg, compared to 77-150 mg of caffeine in a cup of coffee (Attipoe et al. 2016, Kelly, Prichard 2016, Nowak, Jasionowski 2016).

A literature review uncovers a wide variety of substances added to ED. According to one performed analysis, there were over 70 different inorganic and organic compounds and substances in energy drinks. Manufacturers declared the prevalence of numerous substances, for example sodium citrate, CO_2, taurine, caffeine, inositol, riboflavin, niacin, pantothenic acid, potassium sorbate, sodium benzoate, glucose syrup, ginseng extract, maltodextrin, calcium lactate, sodium chloride, phosphoric acid, E150d color, acacia gum, sorbic acid, benzoic acid, anthocyanins, ascorbic acid, gum Arabic, glycerol esters and vegetable resin, carotenes, zinc gluconate, potassium iodide, magnesium citrate, carrot concentrate, E101 dye, glucose-fructose syrup, potassium citrate, glucose, sucrose, sodium carbonates, magnesium carbonates, sucrose isobutyrate acetate, calcium phosphate, E160e dye, L-carnitine, l-leucine, l-isoleucine, l-valine, brilliant blue, ammonia caramel, cyclamates, saccharin, E150c dye. In contrast, the caffeine quantity of the energy drinks tested ranged from 28.944 mg 100 mL^{-1} in sample NE13 to 37.162 mg 100 mL^{-1} in NE10. The manufacturer's declared caffeine quantity was 32 mg 100 mL^{-1}. Most of the samples had a higher caffeine quantity than what the manufacturer had declared (Żukiewicz-Sobczak et al. 2018).

Analyses show that the lifetime prevalence of ED consumption worldwide was estimated at 54.7%, 43.4% people consumed ED in the last

12 months, 32.3%, in the last 30 days, 21.6% in the last 7 months, 3% in the last 30 days, 21.6% in the last 7 days and 8.82% daily (Aonso-Diego et al. 2024). In the EU, one in ten people consumes ED at least once a day (European Statistical Office 2022).

Based on the analysis of the results of a survey conducted from July 2019 to February 2020, The National Institute of Public Health (PZH) – National Research Institute showed that reaching a potentially dangerous level of ED consumption by drinking it at least once a week was a problem most often among adult men (17.6%), boys aged 10-17 (9.6%) and adult women (7.4%). Assuming that it is particularly dangerous to consume ED more than once a week, this constitutes a problem most often affecting adult men (9.7%), boys aged 10-17 (4.6%), and women aged 18-64 (4.2%). The frequency of ED consumption in different demographic groups is presented in another study (Stoś et al. 2021).

It should be assumed that data related to adverse symptoms associated with ED consumption are based on patient-reported signs and symptoms, and are probably underestimated because most consumers may not recognize ED as a toxic substance. It is therefore necessary to improve our understanding of ED consumption as a phenomenon and the health effects associated with it.

Recognition of the negative health effects of consuming ED has resulted in Poland banning their sale to children and young people under the age of 18, effective from 1 January 2024.

With the ban on the sale of ED to minors on the Polish market, educational measures should be taken to make broad sections of society aware of the harms associated with their consumption with a view to changing habits and lifestyles (e.g. advertising campaigns in the mass media, educational classes in schools, etc.).

MATERIALS AND METHOD

An analysis was carried out, covering a range of scientific content taken from PubMed, the English-language online database of the National Library of Medicine, National Institutes of Health, Bethesda, MD, USA (http://www.ncbi.nlm.nih.gov/PubMed), SCOPUS, and Google Scholar. It included articles in the field of medicine which reported findings regarding adverse health effects of ED consumption. Literature published in scientific article databases between 2020 and 2024 was reviewed, setting a 5-year time frame for analysis under the assumption that it would include the most recent scientific reports on the topic in question. In the process of searching for scientific articles, advanced search options were used, based on keywords in English and Polish, or their combinations (step 1, Table 2) and the established time

Table 2

Step one of the analysis of the literature trends on the basis of key words

Key words	energy products, energy drinks impact on health, energy drinks health risks, napoje energetyzujące objawy niepożądane

frame (2020-2024). Reviews, conference proceedings, letters to the editor, book chapters, as well as conference and training notes were not included in the review and were excluded from the analysis.

RESULTS AND DISCUSSION

The analysis confirmed that the scientific database PubMed (as of December 12, 2024) contains 2,230 publications on the consumption of energy drinks and their impact on human health in 2020-2024. Table 3 shows a quantitative account of publications on energy drinks and their impact on health in the analyzed period. Of the 2,230 articles (100% of publications), publications emerging in the search using the keyword combination "energy drinks" accounted for 61.20% (n=1,365) of all publications, articles on energy drinks impact on health constituted 9.00% (n=202) of all articles, while those discussing energy drinks health risks accounted for 14.80% (n=330), and those on energy drinks side effects constituted 15.00% (n=333) of all articles. Ten papers directly addressing possible health effects associated with ED consumption were analyzed in detail, as illustrated in Table 4.

Table 3

Publications regarding energy drink consumption and their effect on consumer health in 2020-2024

Year of publication	Number of publications based on searching by keywords				
	energy drinks	energy drinks impact on health	energy drinks health risks	energy drinks side effects	Total
2020	314	38	68	76	496
2021	320	47	78	82	527
2022	281	43	79	75	478
2023	223	42	50	53	368
2024	227	32	55	47	361
Results in total	1 365	202	330	333	2 230

The source: developed by the authors, on the basis of PubMed database (http://www.ncbi.nlm.nih.gov/PubMed)

Table 4

Detailed characteristics of the studies included in the present paper, dealing with health consequences related to energy drink consumption

Author of the study	Country of study	Study design (level of evidence)	Number of people and gender tested for consumption of energy drinks	Sample age in years, mean ± SD (range)
Masengo et al. 2020	Canada	two-stage stratified cluster sample design	5538 (2330 males, 3208 females)	15.3
Wee et al. 2021	Korea	cross-sectional study	129 809 (67 056 males, 62 753 females)	12-18
Khan et al. 2022	Pakistan	cross-sectional study	104 (84 males, 20 females)	18.5±4.5
Oberhoffer et al. 2022	Germany	randomized study	27 (males 14, 13 females)	14.53±2.40
Costa et al. 2023	Egypt	cross-sectional study	350 (250 males, 100 females)	15-21
Faris et al. 2023	UAE	cross-sectional design	4648 (3021 males, 1627 females)	14-18
Hamdy et al. 2023	Iraq	cross-sectional study	438 (226 males, 212 females)	18-25
McMillan et al. 2024	USA	case report	1 male	62
Granda et al. 2024	Poland	survey study	1530 (756 males, 744 females)	10-14 lat 12.0±1.2
Mahmood et al. 2024	Portugal	prospective study	30 females	19.96±1.13

HEALTH HAZARDS

In one study analysing a sample of 33,259 participants, including 9911 adolescents (ages 12-19); 12,103 young adults (ages 20-39); and 11,245 middle-aged adults (ages 40-59), the prevalence of ED consumption was shown to have increased significantly among adolescents (from 0.2% to 1.4%, p=0.028), young adults (from 0.5% to 5.5%, p<0.001), and middle-aged adults (from 0.0% to 1.2%, p=0.006). The results of this study suggest that the prevalence of ED consumption has increased significantly over the past decade among adolescents, young adults and middle-aged adults in the US, and that these beverages are the main source of caffeine among those who consume them (Vercammen et al. 2019).

A systematic review of scientific articles that included 32 studies drawing results from a total of 96,549 people found that the most commonly reported adverse effects of ED consumption among children were insomnia

(35.4%), stress (35.4%) and depressed mood (23.1%). Meanwhile, the most commonly reported adverse effects in the adult population were insomnia (24.7%), restlessness/hand tremor (29.8%) and gastrointestinal distress (21.6%) (Nadeem et al. 2021).

Literature shows that ED containing caffeine cause a pro-nociceptive state of cortical hyperexcitability, a condition related to acute and recurrent daily headaches (Jovel, Mejía 2017). Meanwhile, excessive consumption of caffeine-containing ED may trigger migraines (Mostofsky et al. 2019).

Caffeine has been shown to trigger seizures in people who are sensitive to it, especially when they are sleep deprived. After drinking a large amount of an ED, some people began to experience seizures without any signs of intracranial or electroencephalography abnormalities (Subaiea et al. 2019).

Young and otherwise healthy patients who had been consuming ED and sought out medical help have been diagnosed with supraventricular and ventricular arrhythmia, coronary spasms, myocardial ischemia/infarction, atrial fibrillation, syncope, aortic dissection, cardiomyopathy, cardiac arrest and sudden cardiac death, among others (Mangi et al. 2017, Wikoff et al. 2017, Ehlers et al. 2019, Protano et al. 2023).

In addition to cardiovascular problems, caffeine in ED can also lead to the development of depression, anxiety symptoms, or even delusions and hallucinations. This can be explained as the body reacting to increased levels of cortisol in the blood, which is produced in excessive amounts when under the influence of caffeine. This can trigger the emergence of hallucinations and other mental conditions (Hernandez-Huerta et al. 2017, Mannix et al. 2024).

Research covering the aspect of ED consumption in relation to cardiovascular incidents between 2003 and 2023 has extensively studied the potential cardiovascular implications of ED consumption. A study has uncovered a relationship between ED consumption and adverse cardiovascular events such as elevated blood pressure, arrhythmias and even myocardial infarction or cardiac arrest (Chami, Primio 2024).

Substances in ED can have harmful effects on the sensory system. There are several negative effects associated with excessive ED consumption, including headaches, palpitations, anxiety and insomnia, while more serious side effects are observed in clinical data (Peacock et al. 2016).

Research points to a relationship between ED consumption and mental health issues among adolescents. These problems were associated with a higher risk of moderate to severe levels of psychological distress, suicidal thoughts and suicide attempts (Kim et al. 2020, Kaur et al. 2020).

Studies show an association between ED intake and mental health problems among adolescents. These problems were associated with a higher risk of moderate to severe levels of psychological distress, suicidal thoughts and suicide attempts (Kaur et al. 2020, Kim et al. 2020).

Adolescents investigated for the purpose of research reported negative health effects of ED consumption including increased urination, tachycardia, insomnia, headache and anxiety (Subaiea et al. 2019, Alafif et al. 2021).

ED can also lead to the development of gastrointestinal disorders. They also serve as etiological explanations of some cases of acute hepatitis, acute pancreatitis and renal failure with acute kidney injury (Costantino et al. 2023).

There are several reports which investigated cases of acute pancreatitis in adult patients related to the consumption of energy drinks (Uwaifo 2019, Randhawa et al. 2022).

Findings from chemical analyses indicate that these drinks are highly acidic, which, combined with their high content of non-reducing carbohydrates (mainly sucrose), results in their high ability to erode dental enamel (Kakouris et al. 2023).

Taking into account the fact that the effects of EDs on the human body are not fully understood, there is a need to follow up on the results of research regarding their negative effects.

A study of 5,538 participants indicated that ED consumption is strongly and differentially associated with mental problems among middle and high school-aged adolescents. The results suggest that ED consumption is a marker or risk factor for mental disorders and suicidal tendencies among adolescents. The relationship between ED consumption and negative mental health outcomes was much stronger among boys and high school students (Masengo et al. 2020).

Assessing the relationship between ED consumption and various allergic conditions, including asthma, allergic rhinitis and atopic dermatitis, was the aim of one study involving a group of 129,809 participants. The study found that 113,507 respondents reported consuming ED once a week, ED were consumed 1-2 times per week by 12,048 respondents, 3-4 times per week by 2,493 survey participants, 5-6 times per week by 810 respondents and ≥7 times per week by 951 participants. Based on an analysis of the survey results, frequent ED consumption has been shown to be associated with the occurrence of allergic diseases, including asthma, allergic rhinitis and atopic dermatitis in adolescents (Wee et al. 2021).

The high prevalence (66.7%) of ED consumption among professional athletes was shown in a study of 104 athletes. Dental cavities, as the most common oral health problem, was reported by 63.5% of the professional athletes surveyed. With regard to periodontal health, a high prevalence of gingivitis (46.1%) and periodontitis (26.9%) was observed. A large number of athletes also reported that during the previous year, oral problems affected their ability to undertake daily activities (65%) or negatively affected their participation and performance in sports activities or events (37%). The study found that competitive athletes who frequently consumed ED drinks have poor oral health, despite their self-declared good oral health and hygiene

habits. Dental cavities, periodontal disease and dental erosion were common, and periodontal disease significantly affected the ability to perform daily activities and athletic performance (Khan et al. 2022).

A pediatric pilot study of 27 participants examined the acute effects of ED consumption on blood pressure and heart rate in healthy children and adolescents. The study showed a significant temporary increase in systolic blood pressure (SBP, mm Hg) and diastolic blood pressure (DBP, mm Hg) in healthy children and adolescents after ED consumption. Compared to placebo intake, mean SBP increased to 5.23 mm Hg and mean DBP increased to 3.29 mm Hg after drinking ED. The results of this study suggest that children's cardiovascular systems may respond even more strongly to the ingredients found in ED (Oberhoffer et al. 2022).

The study of 30 young women between the ages of 18 and 22 after ED (250 ml Redbull®) consumption showed that the mean values of systolic blood pressure were equal to 118.03±1.39 mm Hg at baseline, 119.33±1.81 mm Hg 30 mins post-intake, and 118.60±1.79 mm 60 min post-intake. Meanwhile, DBP values were 74.20±1.24 mm Hg at baseline, 74.47±1.19 mm Hg 30 min post-intake, and 76.03±1.39 mm Hg 60 min post-intake. The heart rate was 81.47±2.48 bpm at baseline, 75.87±2.24 bpm 30 minutes post-intake and 74.33±2.19 bpm 60 minutes post-intake. These results indicated that the consumption of Redbull®, an energy drink, was followed by a decrease in carotid and middle cerebral artery velocities, as well as a decrease in cardiac output associated with a lowered heart rate and a slight, but not statistically significant, increase in systolic and diastolic blood pressure (Costa et al. 2023).

A study of 4,648 school-aged children in the United Arab Emirates found that adolescents who consume ED were observed to increasingly report poor self-rated mental health symptoms, such as feelings of anger, nervousness, anxiety and loneliness, as well as emotional and behavioral problems. The findings indicate a relationship between unhealthy eating behaviors (such as skipping breakfast and eating less fruits and vegetables), as well as unhealthy lifestyle (long time spent in front of a computer screen, poor sleep) and ED intake. A relationship has been observed between ED intake and negative eating habits involving frequent snacking and consumption of high-energy fast food (Faris et al. 2023).

The results of the study conducted on a group of 350 participants revealed that 38.5% of the study sample declared that they had consumed ED in the past, 14.2% consumed them more than once a day, 17.9% consumed EDs daily, 42.9% consumed ED three to five times a week, and 25.0% of them drank ED two to three times a week. The analysis of the results showed that respondents suffered from negative consequences of ED consumption, such as increased urination in 51.4% of participants, followed by tachycardia (40.0%), insomnia (35%), headache (27.1%) and anxiety (20.7%) (Hamdy et al. 2023).

A case study investigated an adult male patient with chronic pancreatitis pain associated with excessive ED consumption. The study illustrated the case of a 62-year-old man who was admitted to the hospital due to an exacerbation of chronic pancreatitis after months of consuming ED containing 160 mg of caffeine. The report showed that the patient likely had early stage chronic pancreatitis, experiencing periodic episodes of pain without any other significant complications identified. A causal relationship between ED consumption and exacerbations of chronic pancreatitis pain could not be established based on the diagnostic process. The acute onset of pain after excessive ED consumption in the absence of any additional explanation for the exacerbation of chronic pancreatitis makes EDs the most likely cause of chronic pancreatitis pain (McMillan et al. 2024).

According to a study of 1,530 adolescents participating in extracurricular organized sports activities, almost half (46.4%) of respondents declared being ED consumers (significantly more boys than girls: 53.0% vs. 47.0%, p=0.010). The group of ED consumers was significantly dominated by boys (53.0% and 47.0% of girls, respectively) and those aged 12 and 13. The percentage of ED consumers increased with age, from 27.2% among 10-year-olds to 65.4% among 14-year-olds. The most frequently reported frequency of ED consumption was "less than once a month" (56.9%), followed by "1-3 times a month" (20.8%). The percentage of adolescents consuming ED daily was relatively low (3.6%). Among ED consumers, infrequent consumers constituted the largest group (77.7%), followed by frequent consumers (17.3%). Very frequent consumers were a minority (5%). The mean daily caffeine intake of ED consumers was 20.8±81.2 mg. The mean daily intake was significantly higher among boys compared to girls (p<0.05). The highest intake was observed in the 13-year-old demographic, and the lowest in 10-year-old participants (41.7±142.1 mg and 6.3±11.9 mg, respectively). The results of the study indicate that ED intake is relatively common among physically active Polish adolescents (Granda et al. 2024).

According to data obtained from a study of 438 medical students, the prevalence of caffeine-containing ED consumption was surprisingly high (70%, n=307). The majority of subjects (79%, n=344) experienced tachycardia. Additionally, ED drinkers had significantly higher rates of elevated blood pressure (56.4%, n=173), palpitations (63.1%, n=194) and chest discomfort (73.2%, n=225) compared to non-ED drinkers. These results were highly significant (p<0.0001). ED drinkers had significantly higher rates of fatigue (79.3%, n=243) compared to non-drinkers (p<0.0001). 74.4% (n=228) of ED drinkers experienced headaches, and 74.7% (n=229) exhibited an unhealthy sleep pattern (less than six hours of sleep nightly). The data showed that 23.4% (n=101) of the subjects occasionally manifested aggressive behavior. Based on the results obtained, it can be assumed that ED consumption can have a significant impact on several cardiovascular and psycho-behavioral parameters, in particular tachycardia, elevated blood pressure, palpitations, fatigue, lethargy, and aggression (Mahmood et al. 2024).

CONCLUSIONS

The popularity of ED poses a serious challenge to public health and the education system. The complex composition of ED makes it difficult to assess their impact on health. The analysis of available literature indicates that excessive ED consumption can lead to a variety of medical symptoms. A further analysis is needed to comprehensively understand the effects of ED on the human body, with a particular focus on their consumption by children and adolescents.

The incidence of a large number of health problems related to ED consumption is mostly a result of the excessive concentration of caffeine and other substances affecting the health. The occurrence of adverse situations justifies the urgent need to introduce widespread prophylactic educational measures regarding ED consumption and healthy lifestyle habits.

Author contributions

J.C. – designed research. J.C., M.C.D, P.S., M.W. – analyzed data, and wrote the manuscript. All authors read and approved the manuscript.

Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The present research did not receive any specific donation from any funding agency in the public, commercial or non-profit sector. Artificial intelligence (AI) was not used in the creation of the paper.

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