

ENERGY DRINK USE DISORDER – A REVIEW OF THE LITERATURE

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Abstract. Energy drinks (EDs) are non-alcoholic, caffeine-rich drinks (>15mg/100ml), also containing other psychoactive substances, e.g. taurine. Currently, the ICD 11 and DSM 5 classifications do not specify any “Energy drink use disorder.” The purpose of this article is to review the research to date on disordered use and addiction to energy drinks. In the review, we also present an overview of contemporary concepts of the classification position of the disordered use/dependent pattern of use of energy drinks. The results of a study by Holubcikova et al. showed that men are twice as likely to consume energy drinks as women. In a survey of young adults and adolescents in Poland, 67% of the interviewed group (n=29629) used Eds, of which 17% on a regular basis.

Keywords: caffeine; taurine; substance use disorders; toxicity; personality traits

1. INTRODUCTION AND DEFINITIONS

Energy drinks (EDs) are non-alcoholic beverages, but rich in caffeine >15mg/100ml. Energy drinks vary in their composition and percentage of individual ingredients. The psychoactive substances contained in each

EDs are caffeine and taurine. Other psychoactive substances used in EDs are: l-carnitine, glucuronolactone, B vitamins, ginseng and guarana, the quantitative content of these substances is described on the label of the drinks. Some energy drinks contain additional amounts of caffeine, not included on the labels attached to them, which come from added ingredients like kola nuts, yerba maté, cocoa. While soft drinks with a high caffeine content (96mg/l) emerged in Europe and Asia in the 1960s, energy drinks, which contain a greater number of psychoactive substances, including taurine, and high concentrations of caffeine (320mg/l/), initially in Europe became available to consumers with the introduction of the Red Bull[®] brand beverage to Austria in 1987 and then to North America in 1997 [Reissig, Strain, and Griffiths 2009, 1-10]. Consumption of energy drinks is on the rise from 2015 to 2018, rising from 10 billion liters to more than 15 billion liters/year, despite what might seem like widespread knowledge of their harm.¹ In 2015, global consumption of EDs reached 11.5 billion liters/year. Studies conducted between 2007 and 2018 demonstrated the toxicity of these drinks to animals and humans, and analyzed patterns of use. In the ICD-11 and DSM-5, the use of energy drinks is cited as an example of a source of caffeine in the description of caffeine use disorder. Currently, the ICD 11 and DSM5 classifications do not distinguish: “Energy drink use disorder.” There is a hypothesis that the abuse of energy drinks is not only due to caffeine addiction. Pathological use of energy drinks may be a behavioural addiction. And the function of taurine in the development of EDs addiction has not been ruled out. The purpose of this article is to review the research to date on disordered use and addiction to energy drinks. In the review, we also present, an overview of contemporary concepts of the classification position of the disordered use/dependent pattern of use of energy drinks.

2. LEGAL ASPECTS OF ENERGY DRINKS USAGE

In the European Union’s legislative system, there is no document in which the name “energy drink” is used. In most cases, it is a reference to a non-alcoholic but caffeine-rich soft drink, including Regulation (EU) No. 1169/2011 on the provision of food information to consumers.² Beverages with a caffeine content of more than 15 mg/100 ml must carry the warning: “High caffeine content. Not recommended for children and pregnant or breastfeeding women.” in the same field as the name

¹ Statista Research Department, Dec 2, 2016, Global energy drink sales volume, 2015/2018 | Statistic | Statista, <https://www.statista.com/statistics/639965/sales-volume-energy-drinks-worldwide/> [accessed: 11.08.2022].

² Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.

of the beverage, followed by a reference to the caffeine content expressed in mg per 100 ml. This has been mandatory since 2014 [Binder and Gortosos 2015]. In Denmark, the production and distribution of EDs is banned; Denmark's National Environmental Protection Agency Poison Ordinance prohibits the inclusion of caffeine in food except for 15 mg/100 ml in soft drinks. In the UK and Germany, the restriction on sales applies until the age of 16, while in Lithuania and Latvia it applies until the age of 18³ [Schroeder 2016, 400]. In the US, EDs are classified as either a conventional food or a dietary supplement; some EDs, e.g. Monster Energy[®], Rockstar[®] are branded as a dietary supplement, while others, e.g. Red Bull[®] as a conventional food. This is due to the Dietary Supplement Health and Education Act of 1994 (DSHEA); according to it, a dietary supplement, unlike a conventional food, cannot contain additives (in the case of EDs-caffeine) that are not used in the production of conventional foods, unless it has been approved by the FDA and is deemed safe and can be used without prior FDA approval [Generali 2013, 5-9]. This is despite the fact that caffeine is recognized as a drug. Furthermore the U.S. Dietary Supplement Health and Education Act of 1994 (DSHEA), does not force manufacturers of energy drinks to list herbal supplement ingredients [Seifert et al. 2011, 511-28].

3. EFFECTS OF USING ENERGY DRINKS ACCORDING TO ICD-11 AND DSM-5

In the WHO's classification in revision 11 (ICD-11), behavioural and substance addictions are included in the group of disorders caused by either psychoactive substance use or addictive behaviours. According to the ICD-11, the addiction syndrome includes behavioural, cognitive and physiological symptoms that develop after repeated use of a substance or specific repetitive rewarding and reinforcing behaviours, which typically include a strong need to take the drug or perform an activity, difficulty controlling its use or behaviour despite awareness of harmful consequences, preference of taking the drug or addictive behaviour over other activities and commitments, increased tolerance, and sometimes the presence of physical symptoms of abstinence syndrome.⁴ A similar change has occurred in the DSM-5, compared to the previous version. The chapter that classifies substance use disorders – “substance-related disorders” – is now defined as – “substance-related and addictive disorders.” The changes in the classifications

³ Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

⁴ ICD-11 for Mortality and Morbidity Statistics (Version: 02/2022), <https://icd.who.int/browse11/lm/en#/http%3a%2f%2fid.who.int%2fclid%2fentify%2f334423054> [accessed: 26.10.2022].

are based on current knowledge from ongoing research that addiction is a heterogeneous disorder whose subtypes include specific substance use disorders and addictive behaviour [Masiak, Maciejewski, Wallace, et al. 2016, 11-15]. Substance use disorder is currently diagnosed based on the – following DSM5 criteria. The disorder is characterized by impaired control of use, risky use, substance use impairs the patient’s social functioning, and pharmacological criteria (tolerance and withdrawal symptoms) are additionally used. DSM 5 classifies pathological gambling as an addictive activity, this is due to new evidence provided by research on the pathophysiology of substance use disorders and impulse control disorders. Among other things, studies comparing alcohol dependence and pathological gambling have shown in both disorders low concentrations of the serotonin metabolite 5-hydroxy-indole-acetic acid in cerebrospinal fluid; reduced platelet monoamine oxidase levels, considered a peripheral marker of serotonin function; and a clinical response to 5-HT1 and 5-HT2 receptor agonists [Potenza 2006, 142-51]. In the ICD-11 classification, a separate diagnostic unit classified within addictive behaviour disorders are pathological gambling and pathological video or analog game playing, and there are also diagnostic units in the classification to diagnose behavioral addiction, which is different from gambling disorder or gaming use disorder. Other behavior that can be diagnosed as addictive must be characterized by symptoms that share basic clinical features with other disorders caused by addictive behavior. These include a persistent pattern of repetitive behavior in which the person demonstrates impaired control over the behavior (e.g., onset, frequency, intensity, duration, termination, context); an increase in the priority of the behavior to the extent that it takes precedence over other life interests and daily activities; and continuation or escalation of the behavior despite negative consequences (e.g., family conflict, poor academic performance, negative health effects).⁵ For other pathological behaviors, such as compulsive use of the Internet, sex, shopping, eating or stealing, there have also been studies comparing their pathophysiology with addictive disorders, but not enough research has yet been shown to prove their unequivocal pathophysiological and clinical similarities with disorders classified together with addictions [Grant and Chamberlain 2016, 300-303].

4. PHYSIOLOGICAL ASPECTS OF USING ENERGY DRINKS

4.1. Caffeine

The most studied psychoactive substance in energy drinks is caffeine, which has psychostimulant effects [Addicott 2014, 186-92]. The mechanism

⁵ Ibid.

of action of caffeine in non-toxic doses is based on antagonism of adenosine receptors (A1, A2A). Chronic caffeine consumption causes a “down-regulation” of A1 receptors; caffeine then has little effect on the A1 receptor and a predominant effect on A2A receptors [Rossi, De Chiara, Musella, et al. 2010, 525-31]. Antagonism of A2A adenosine receptors indirectly down-regulates CB1 receptors, suggesting that the A2A-CB1 receptor interaction plays a major role in the development of caffeine addiction [ibid.]. A1 receptors are located at dopaminergic terminals in the striatum. Caffeine regulates the density of the dopamine transporter in the striatum – the nucleus accumbens and prefrontal cortex. Caffeine has also been found to modulate GABA-A receptor activity through its effects on benzodiazepine receptors [Myers, Johnson, and McVey 1999]. Genetic factors play an important role in caffeine consumption. The heritability of susceptibility to habitual caffeine consumption has been estimated at 36% to 58%. Cornelis et al. in their meta-analysis identified 8 loci associated with caffeine use; they lie close to loci of genes involved in caffeine pharmacokinetics: ABCG2, AHR, POR and CYP1A2; in caffeine pharmacodynamics: BDNF and SLC6A4. An association between caffeine use and the GCKR and MLXIPL genes has also been identified, but the link between their molecular function and caffeine use is unknown. Analyses of the chemical composition of EDs have shown that a single dose in a serving (250ml) of a beverage provides 3 mg of caffeine/kg body weight [Jiménez, Díaz-Lara, Pareja-Galeano, et al. 2021, 2944]. Caffeine poisoning is a potential adverse effect of energy drinks. Typical symptoms of caffeine intoxication include restlessness, nervousness, excitement, chaotic thinking and speech, psychomotor agitation, insomnia, increased physical performance, increased diuresis, gastrointestinal disturbances, muscle cramps, tachycardia and other heart rhythm disturbances. The effect of caffeine use depends on the dose, for example, 250 mg increases excitement, while 500 mg increases irritability [Sandeep, Fleming, and Morrow 2004, 211-26]. In cases where doses close to the lethal dose were taken, hypertension, hypotension, arrhythmia and convulsions, and even death were observed [Yamamoto, Yoshizawa, Kubo, et al. 2015, 33-36]. Studies have shown that the lethal blood concentration of caffeine is >100 µg/ml [Takayama, Waters, Hara, et al. 2016, 228-33].

In the ICD-11 classification, there is a diagnostic category: “Caffeine Use Disorder,” which can be diagnosed when a patient consumes energy drinks and, at the same time, the clinical picture meets the criteria for an addictive syndrome.⁶ Although researchers explain the effects of energy drinks by the psychostimulant effects of caffeine, studies clearly do not support that

⁶ Ibid.

only caffeine and its addictive potential contributes to the abuse of energy drinks [Kemps, Tiggemann, Cibich, et al. 2019].

4.2. Taurine

Taurine, is the active ingredient in energy drinks [Zucconi, Volpato, Adinolfi, et al. 2013, 394]. Taurine meets many of the criteria necessary to be considered a neurotransmitter, but no taurine-specific receptor has yet been discovered in the nervous system. However, taurine is known to be a GABA-A receptor agonist, and its affinity depends on the conformation of the subunits that make up this receptor [Ochoa-de la Paz, Zenteno, Gulias-Cañizo, et al. 2019, 289-91]. The concentration of taurine in a single ED serving ranges from 750 to 1,000 mg, where the average diet contains 40 to 400 mg per day. The Mayo Clinic recommends taurine intake of no more than 3,000 mg per day [Curran and Marczynski 2017, 1640-648]. Taurine is a psychoactive substance that stimulates GABAergic signaling in the hippocampus and olfactory bulb [Ochoa-de la Paz, Zenteno, Gulias-Cañizo, et al. 2019, 289-91]. The conformations of GABA receptor subunits determine the binding strength of taurine to this receptor. The $\alpha 4$, $\beta 2$ and δ (thalamus) or $\alpha 6$, $\beta 2$ and δ (hippocampus) subunits have the highest affinity for taurine with EC₅₀ (half-maximal effective concentration) of 50 μM and 6 μM , respectively [ibid., 289-91]. In alcohol dependence, there is a systematic decrease in the number of $\alpha 4$ and gamma 1 subunits and an increase in the number of $\alpha 1$ subunits, which are part of GABA-A receptors, changes in the composition of the GABA-A receptor complex explain the molecular mechanism of addiction development [Devaud, Smith, Grayson, et al. 1995, 861-68; Kumar, Fleming, and Morrow 2004, 211-26].

5. ENERGY DRINKS USAGE PATTERNS

The patterns of EDs consumption are well known: the main conscious motives for reaching for the drinks; the dominant psychological characteristics of consumers; and comorbidities. In a systematic review, Nadeem et al. found that 76.7% of students surveyed reported consuming at least 1 energy drink per week to increase energy (24.5%; 2640/10757), to stay awake or mask insufficient sleep (15.7%; 1694/10,757), and to improve concentration while studying (14.1%; 1520/10,757) [Nadeem, Shanmugaraj, Sakha, et al. 2021, 265-77]. 3232 out of 6796 subjects reported combining energizers with other substances (47.6%), with alcohol being the most common (44.6%; 3030/6796). 2.9% of respondents had used other psychoactive substances, such as marijuana, ecstasy, cocaine and other stimulants [ibid.]. EDs used together with alcohol, was defined as (Alcohol mixed Energy Drinks

– AmED). Combining energy drinks with alcohol increases the potential for alcohol abuse, compared to consuming alcohol alone. Studies have shown that there has been an increase in the prevalence of binge drinking combined with energy drink consumption over the past seven years [Howard and Marczynski 2010, 553-61]. The synergistic effect of alcohol and taurine can cause epileptic seizures [Calabrò, Naro, and Bramanti 2016, 723-32]. The results of a study by Holubcikova et al. showed that men are twice as likely to consume energy drinks as women [Holubcikova, Kolarcik, Madarasova Geckova, et al. 2017, 599-65]. Advertisements for EDs have been analyzed for the presence of persuasive cues according to the Elaboration Likelihood Model. Terms such as “power” and “energy” are used; therefore, due to their, implicit association with physical activity, these products may be more attractive to men than to women [Bae, Kim, Choi, et al. 2019, 153-60]. In addition, advertisements depict athletes engaged in extreme sports, suggesting that EDs are healthy and help you achieve your goals [Bleakley, Ilithorpe, Jordan, et al. 2022, 16010]. In a survey by Nowak et al, respondents declared that ads alluding to power and strength were the most likely to prompt them to reach for EDs [Nowak and Jasionowski 2015, 7910-921]. Despite conscious motives for reaching for energizers, to increase energy or strength, students’ physical activity and sedentary leisure activities were not significantly associated with regular consumption of energy drinks [Nuss, Morley, Scully, et al. 2021, 64]. In a survey of young adults and adolescents in Poland, 67% of the study group (n=29629) used EDs of which 17% used them systematically. 36% said EDs were harmful to health, and only 6% responded that they were not; the study group included people who used energy drinks despite awareness of their harmful effects [Nowak and Jasionowski 2015, 7910-921]. Chronic users of EDs are more likely to have poor eating habits, including consuming mainly sweetened beverages, juices and fast food [Nuss, Morley, Scully, et al. 2021, 64]. No association of EDs use with vegetable consumption has been observed [ibid.]. Energy drink users are more likely to engage in risky behaviors [Arria, Bugbee, Caldeira, et al. 2014, 87-97]: they are more likely than the control group to smoke cigarettes, use ecstasy; use alcohol riskily [Trapp, Allen, O’Sullivan, et al. 2014, 30-37]; and have casual sexual intercourse [Snipes and Benotsch 2013, 1418-423]. Habitual users of energizers are characterized by higher levels of impulsivity. They were more frequently diagnosed with self-injurious behavior [Bae, Kim, Choi, et al. 2019, 153-60]. Consumption was also strongly associated with sensation seeking and past injuries (reported by 16% and 42% of adolescents, respectively) [Hamilton, Boak, Ilie, et al. 2013, 496-501]. Above that, the following co-occurrences have been observed: ADHD, academic burnout [Nadeem, Shanmugaraj, Sakha, et al. 2021, 265-77], and erectile dysfunction [Marinoni, Parpinel, Gasparini, et al. 2022, 1307-319]. In studies, no higher prevalence of depressive

symptoms or increased anxiety as a personality trait was found in chronic EDs users [Nadeem, Shanmugaraj, Sakha, et al. 2021, 265-77]. A study of 15 – to 16-year-olds found a strong association between caffeine consumption and aggression and violent behavior [Kristjansson, Sigfusdottir, Frost, et al. 2013, 1053-1062; Park, Park, and Kim 2016, 132-39].

Toblin et al. in a study of American soldiers proved a strong link between EDs consumption and aggressive behavior [Toblin, Adrian, Hoge, et al. 2018, 364-70]. Tóth et al. proved that people with a weaker sense of coherence were significantly more likely to be addicted to energizers. A survey study, using the J-MHAT 7 scale, showed that those consuming 3 or more EDs per day felt more stress than respondents who did not consume EDs. Engaging in sports combined with the consumption of EDs does not increase feelings of coherence or reduce vulnerability to stress, although physical activity has been proven to reduce the severity of stress experienced [Tóth, Soós, Szovák, et al. 2020, 1920]. Nadeem et al. in their systematic review alerted that in a group consuming energy drinks more than 1 per day or 3-6 per week, suicidal thoughts and attempts are more frequently recorded [Nadeem, Shanmugaraj, Sakha, et al. 2021, 265-77]. An observational study on American soldiers found that soldiers were more likely to use energy drinks at rest than during physical activity.⁷ Consumption of three or more energy drinks per day was associated with sleep disturbances – insomnia (sleeping ≤ 4 hours per night), resulting in excessive sleepiness at work⁸ [ibid.]. Researchers Kemps et al. using Robinson and Berridge’s “incentive synthesis” theory proved that some energy drink abusers experience abnormalities during associative learning when reaching for EDs, and similar abnormalities have been observed in alcohol and tobacco addicts. They have not been demonstrated by studying coffee consumers [Kemps, Tiggemann, Cibich, et al. 2019, 0226387]. Cognitive bias modification is used in the treatment of associative learning disorder, but the subjects clearly did not reduce their intake of energy drinks as a result of the treatment [ibid.].

CONCLUSIONS

The results of the current study are inconclusive as to whether energy drink use disorder meets the criteria to be distinguished from caffeine use disorder. From the current research, it appears that EDs use has features

⁷ Centers for Disease Control and Prevention (CDC), Energy drink consumption and its association with sleep problems among U.S. service members on a combat deployment – Afghanistan, 2010. *MMWR Morb Mortal Wkly Rep.* 2012 Nov 9;61(44):895-898. PMID: 23134972.

⁸ Ibid.

of addiction – use despite awareness of harmful effects, the need to seek and provide an addictive agent, an increase in tolerance to the effects of the agent, a compulsive need to provide stimuli at the expense of one's health and environment. Research is needed on the harmfulness of taurine and its addictive potential. Further research is needed on the pathogenesis of impaired EDs use and comorbidity with depressive, anxiety and attention deficit disorders. Regulation of labeling, retail restrictions and marketing of energy drinks are needed.

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