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Alcohol Mixed With Energy Drinks (AmED): A Perfect Recipe For Disaster. An Analysis Of AmED Consumption And Potential Health Effects

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ABSTRACT

Introduction and purpose of research

With the surge of popularity of energy drinks, a growing trend of mixing alcohol with energy drinks (AmED) has been observed, particularly among youth and young adults. This review aims to explore both the mechanism of action of this mixture as well as its short- and long-term effects.

Research Materials and Methods

A literature review was conducted using the PubMed database to identify studies on the health effects of alcohol mixed with energy drinks. The search included keywords such as “alcohol mixed with energy drinks”, "alcohol AND energy drinks" and "AmED AND health effects".

Basic results

Studies consistently report an association between AmED consumption and an increased risk of cardiovascular, mental, and kidney diseases, binge drinking and risky behaviors more frequently than those who consume alcohol alone. A common effect among AmED consumers is “false sobriety”, a phenomenon where individuals feel less intoxicated despite consuming high amounts of alcohol. However, due to the limited number of controlled human studies, the precise physiological and molecular interactions between caffeine and alcohol still remain unclear.

Conclusions

The ban on pre-mixed AmED products has not yet yielded satisfactory results. Therefore, governments should explore alternative measures, such as stricter regulations on marketing and sales or public awareness campaigns. This article highlights the issue of mixing alcohol with energy drinks, examining physiological effects, potential health risks, and broader societal impacts. With the growing popularity of this practice, our study emphasizes the need for continued research to guide effective prevention strategies and public health actions.

Keywords

Alcohol mixed with energy drinks, Substances-Related Disorders, Health Risk Behaviours, Alcohol drinking, Energy drinks, Caffeine, Health and activity

Introduction

The consumption of energy drinks (ED) has significantly increased in recent years, particularly among students and athletes seeking enhanced performance and alertness. These beverages typically contain caffeine, sugar, and taurine, which are known to improve cognitive and physical functions (See Figure 1). However, a growing concern is the practice of mixing energy drinks with alcohol, forming what is known as Alcohol Mixed with Energy Drinks (AmED) (Nadeem et al. 2021, Sefen et al. 2022, Pérez-Mañá et al. 2022, Azagba et al. 2013, Verster et al. 2018).

Ethanol (EtOH) consumption alone poses significant health risks, but when combined with ED, it is associated with an even higher incidence of risky behaviors and increased alcohol intake. The added sugar and fruit flavors in ED may improve the taste of ethanol, encouraging excessive consumption. More importantly, AmED impairs the perception of alcohol's sedative effects, creating a false sense of sobriety. This phenomenon is believed to result from caffeine-ethanol interactions, though the effects depend on the doses of both substances (Tarragon 2023).

The health consequences of AmED consumption are both short- and long-term, including arrhythmias, cardiovascular alterations, neurological effects, and transient nephrotoxicity (Azarm et al. 2024, Díaz et al. 2016, Costa-Valle et al. 2018, Cheng et al. 2012). Additionally, AmED users are more likely to engage in illicit drug use, high-risk sexual behavior, and dangerous driving. They are also at increased risk of developing alcohol dependence and addiction patterns (Sefen et al. 2022, Scalese et al. 2023).

Despite regulatory measures, such as the US Food and Drug Administration‘s (FDA) ban on pre-mixed AmED, the issue persists, as individuals continue to mix these beverages themselves (Vieno et al. 2018, De Giorgi et al. 2022). Young adults and students remain the largest consumer group, but reports also indicate AmED use among underage drinkers and even pregnant women. The growing number of emergency department visits due to AmED intoxication highlights its increasing socioeconomic burden (Marczinski 2015, Tarragon 2023).

In this article, our primary objective was to analyze the multifaceted issue of alcohol mixed with energy drinks by exploring its prevalence, physiological mechanisms, associated health risks, sociocultural dimensions, and consumption patterns, to provide a comprehensive understanding of its impact on public health and individual well-being.

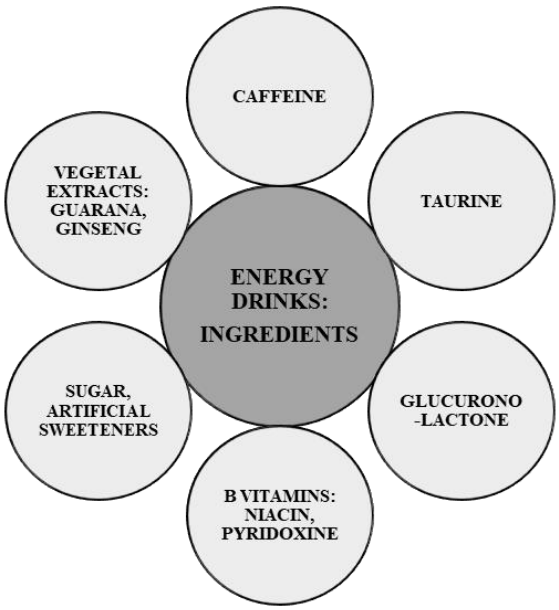

Figure 1. Examples of ingredients present in energy drinks.

Demographics of AmED consumers

AmED consumption is closely linked to the age of users.

Youth and young adults are one of the key age groups using alcohol mixed with energy drinks. (Azagba et al., 2013, De Giorgi et al., 2022) 75% of college students report having consumed AmED at least once in their lives. (Berger et al., 2013) However, it should be mentioned that a decreasing popularity of this practice is being observed among undergraduate students. (De Giorgi et al., 2022) Among learners, those in lower grades (7 and 8) have higher odds of consuming these beverages, so it is decreasing with age. (Azagba et al., 2013).

Another significant factor is the user's gender.

Some studies identify men as more frequent AmED consumers. Among South Korean students who consume alcohol, 22% of men and 13.4% of women reported using AmED. (Oh et al., 2019) This correlation has also been observed within European students (Scalese et al., 2023), as well as in Australia (Pennay et al., 2018).

On the other hand, some studies indicate no correlation between the consumption of alcohol mixed with energy drinks and gender. In a 2013 analysis of college student users, no such association was found. (Azagba et al., 2013) Same for secondary students in Ontario. (Reid et at., 2015)

Differences in the consumption of this combination are also observed depending on the geographical region.

The highest prevalence is observed in the AMR and EUR regions. (De Giorgi et al., 2022) Asian, Asian American and non-Hispanic students are less likely to use AmED (Patrick et al., 2016) Table 1 presents the consumption of AmED depending on the group and geographical region.

Table 1. Consumption of AmED depending on the group and geographical region

Geographical region	Group	Consumption of AmED [%]
Europe		
Slovakia	adolescents	3,4
Poland	adolescent athletes	10,6
Germany	students	20,6
U.K.	students	39,0
Italy	students	44,4
	teenagers	46,1
Turkey	college students	37,2
South America		
Brazil	students and teenagers	12,9 - 31
North America		
Puerto Rico	students	38
Canada British Columbia Nova Scotia	students	20 25,8 25,6

(Azagba et al. 2013, Verster et al. 2018)

There are many potential factors influencing the decision to consume AmED.

There is a significant correlation between the consumption of this mixture and binge drinking. (Verster et al., 2018) Among Ontario secondary school students, it has the strongest association with the habit in question. AmED consumption is most common among weekly binge drinkers, least common among those who binge drink less than monthly, and moderate among monthly binge drinkers. (Reid et at., 2015) Addictive substances that also influence consumption include: smoking cigarettes and electronic cigarettes, using marijuana, other drugs and prescription stimulants. (Verster et al., 2018)

Australian individuals currently studying but without higher education or a university degree are more likely to use AmED. (Pennay et al., 2018) Among college students risk factors are: participating in fraternity/sorority and intercollegiate and intramural athletics. Also living off-campus (especially in houses or apartments with roommates and without parents), having greater fun/social, relax, image motives for alcohol consumption are mentioned. The energy drink industry provides products in exchange for promotion, which may encourage fraternity or sorority members to increase AmED consumption. (Patrick et al., 2017) Furthermore, Canadian

students with higher rates of school absences tend to consume more AmED. (Azagba et al., 2013) There are also protective factors, such as: early morning classes, Honors Program participation, and greater physical/behavioural motives for not drinking. (Patrick et al., 2017)

Money can be another predictive factor, but there are not many scientific studies discussing this factor. Canadian high school students with higher weekly expenditures are more frequent users of AmED. (Azgaba et al., 2013)
In Ontario, students with weekly expenses exceeding $100 are more likely to consume this combination compared to those spending $1–20. (Reid et al., 2015) The same applies to individuals with greater earnings. (Azgaba et al., 2013)

Consumption patterns

An additional important detail is the frequency of AmED consumption.
In the Australian society, the majority consumes AmED monthly or less (online survey – 80,9%, street survey – 53,4%). Rest is using them weekly to monthly (in the order as before 16,4%, 36,3%) or more frequently than weekly (2,6%, 10,3%). (Pennay et al., 2018) In Italy, 36% of students who consume alcohol (56,9% of 450 individuals) ingest AmED more than three times a month. (Sefen et al., 2022)
Most AmED drinkers consume one can of energy drink mixed with alcohol (250 ml) per occasion (57,8%). Additionally, 22,7% report consuming two cans at a time, 9,2% consume three cans, and 10,3% drink more than three cans. These numbers are higher during the heaviest AmED drinking occasions: 34,2% consume one can, 30,7% consume two cans, 13,6% consume three cans, and 21,6% consume more than three cans of energy drinks. (Benson et al., 2021)
AmED consumers can articulate their drinking patterns during a typical weekly drinking session. They display a high level of organization and rarely alter their habits. The reason for establishing this routine is to maximize the benefits of using AmED while minimizing or avoiding adverse effects. Most of them drink between two and five AmEDs throughout the night. The first drink is usually one or two mixes as a "booster," followed by beer, wine, or spirits. Around midnight, they return to AmEDs, consuming between two and five of them. (Pennay and Lubman, 2012)
AmED consumption among young people increases during parties (Sefen et al., 2022). The most common time for consumption by young adults is late at night (Peacock et al., 2013). Extending party time is another important motive for increasing consumption. (Pettigrew et al., 2012) Bars are common places to drink alcohol mixed with energy drinks (Marczinski et al., 2006), as are clubs. Students who are going around with friends more often are more likely to consume AmED. (Scalese et al., 2023)

Alcohol and the central nervous system

Ethanol modifies brain function through its interaction with multiple neurotransmitter systems, primarily by disrupting the balance between gamma-aminobutyric acid (GABA), the principal inhibitory neurotransmitter, and glutamate, the primary excitatory neurotransmitter in the central nervous system (CNS). Short-term ethanol exposure induces transient structural changes in GABA receptor subunits, which leads to an enhanced activity of

the inhibitory GABAergic system. This leads to a shift in balance towards CNS depression. (Olsen and Liang, 2017) Furthermore, ethanol increases extracellular adenosine concentrations by stimulating adenosine release and inhibiting its reuptake through A1 and A2A adenosine receptors. (Butler and Prendergast, 2012)

Low concentrations of ethanol (5–10 mmol/L) lead to behavioral disinhibition and exhibit anxiolytic effects, whereas moderate ethanol concentrations (15–20 mmol/L) impair motor coordination and induce sedation. Higher ethanol concentrations (between 20 and 50 mmol/L) cause various depressive effects on the CNS, including profound sedation, amnesia, emesis, hypnosis, and eventually unconsciousness. (Harrison et al., 2017) The biochemical, psychological, and behavioral changes induced by ethanol administration are transient and typically normalize within a few days. (Olsen and Liang, 2017)

Caffeine and the central nervous system

Caffeine is a psychostimulant. The fundamental neuropsychological effect of its action is psychomotor activation and reinforcing effects. Caffeine mechanism of action involves the antagonism of all adenosine receptor subtypes, predominantly A1 and A2A, thereby attenuating the inhibitory effects of adenosine. This reduction in adenosine-mediated inhibition enhances dopaminergic system activity, exerting a stimulatory effect on the CNS. Additionally, caffeine interacts with many other molecular targets in the brain, including ryanodine receptors, γ-aminobutyric acid (GABA) receptors, and cyclic nucleotide phosphodiesterase isoenzymes. (Rodak et al., 2021)

The neurophysiological and behavioral effects of caffeine are dose-dependent. Low doses of caffeine (250 mg) predominantly produce beneficial effects, such as mood enhancement, heightened alertness, reduction of fatigue and improve cognitive performance. Conversely, high doses of caffeine (500 mg) are more likely to induce adverse effects, including anxiety, nervousness, irritability and tachycardia (Kaplan et al., 1997)

Ethanol mixed with Caffeine - effects on the CNS

Caffeine and ethanol, when administered individually, exert distinct effects on the CNS. Whereas when mixed, they interact pharmacologically, modulating the functioning of the nervous system on multiple levels. The pharmacological interactions between caffeine and ethanol have been studied in humans and animal models for decades, but the exact molecular mechanisms underlying their combined effects are not yet fully understood.

As previously mentioned, both alcohol and caffeine interact with adenosine neurotransmission, and these interactions play a pivotal role in the effects observed following the consumption of AmED. Caffeine mitigates the sedative effects of alcohol by antagonizing adenosine A1 receptors. At the same time, alcohol increases adenosine tone, which can counteract the anxiety-inducing effects of caffeine. (Ferré and O'Brien, 2011) Furthermore, caffeine's blockade of A2A receptors increases the release of dopamine, which alleviates alcohol-induced sedation and enhances the reinforcing effects associated with alcohol consumption. (Sefen et al., 2022) The euphoric effects of low doses of alcohol are enhanced by caffeine-induced increases in dopamine, which stimulates the reward system. (Spitta et al., 2023)

It has been proven that the combination of alcohol and caffeine, compared to each substance alone, leads to increased locomotor activity in rodents. Caffeine, when mixed with a high dose of alcohol, antagonizes the CNS-depressant effects of alcohol, resulting in elevated motor activity compared to pre-consumption baseline levels. This effect is most evident when caffeine is combined with a low dose of ethanol, where both substances synergistically stimulate the CNS. (Hilbert et al., 2013)

In addition, the consumption of AmED introduces potential for interactions between alcohol and a wide array of bioactive compounds other than caffeine present in energy drinks. These interactions remain poorly understood, posing health risks for consumers of alcohol mixed with energy drinks. Further investigation is warranted to clarify these mechanisms and their clinical implications.

The Paradox of Mythical Sobriety

An essential matter related to the consumption of AmED is the phenomenon known as the "paradox of mythical sobriety". This refers to the belief among AmED consumers that they are sober, despite having consumed large amounts of alcohol. The mechanism behind this phenomenon is based on the fact that caffeine counteracts only some of the impairing effects of alcohol, such as reaction time slowing, while leaving many other alcohol-related effects unaffected. (Attwood et al., 2012)

Alcohol-impaired individuals typically experience impulsivity and slowed reaction times, whereas after consuming AmED, individuals remain impulsive but with faster reaction times. As a result, AmED consumers may be more prone to engaging in risky behaviors and exposing themselves to danger. Moreover, AmED consumers often have a disturbed self-awareness of their limitations, as the post-alcohol reaction time impairment is suppressed by caffeine. (Marczinski and Fillmore, 2014)

Marczinski et al. conducted a randomised control trial to test the effects of AmED on cognitive processing and subjective reports of alcohol intoxication. The study involved 18 participants who were assigned one of four drinks (alcohol, energy drink, AmED, or placebo) in four sessions. The results indicated that alcohol impaired both motor coordination and dual-task information processing in both AmED consumers and alcohol-only consumers. In contrast, subjective reports of alcohol intoxication differed between groups, with AmED consumers perceiving themselves as more sober. Furthermore, coadministration of ED with alcohol enhanced feelings of stimulation and reduced perceptions of mental fatigue compared to alcohol alone, which additionally intensifies AmED consumers' confidence in their own sobriety. (Marczinski et al., 2012)

Behavioral Risks of Alcohol Mixed with Energy Drinks

The consumption of alcohol mixed with energy drinks is associated with an increased likelihood of engaging in risky behaviors.

The use of AmED (alcohol and caffeine) leads to various changes in subjective state that pose greater risks for the consumer compared to alcohol alone, including reduced awareness of intoxication, heightened stimulation,

and a stronger urge to consume additional alcohol. (Heinz AJ et al. 2013). The physiological basis for this effect is linked to sedation, which is an interoceptive, protective signal indicating a high level of alcohol intoxication, thereby reducing the desire to continue alcohol consumption. Caffeine masks the sedative effects of high doses of alcohol, which explains the increased tendency to consume alcohol to the point of extreme intoxication observed among consumers of AmED. (Sefen et al., 2022)

Increased alcohol intake not only raises the risk of alcohol poisoning but also impairs judgment to a greater extent (Biggio et al. 2024). In particular, AmED consumption has been linked to a higher likelihood of engaging in risky sexual behaviors, as well as an increased attraction to other substances, including marijuana, cocaine, and ecstasy [(Berger et al. 2013) (Snipes and Benotsch 2013)]. AmED users also show a higher probability of requiring medical attention or experiencing injuries while drinking than those who consume only alcohol (Brache and Stockwell 2011).

According to a Canadian survey, young individuals who consume AmED have shown greater tendency to drive under the influence compared to those who drink only alcohol (Wilson et al. 2018). This may be due to the false sense of sobriety that AmED induces, as the stimulating effects of caffeine in energy drinks can mask the depressive effects of alcohol, leading consumers to feel less intoxicated than they are (Marczinski and Fillmore, 2014).

In addition to these issues, research on alcohol-related aggression indicates that higher consumption of alcohol and caffeinated alcoholic beverages (CABs) may increase the tendency toward indirect aggression. Findings also suggest that while alcohol use, including CABs, does not universally predict aggressive behavior, it can encourage aggression in individuals with impaired impulse control. (Sheehan et al. 2016).

Short-Term Physiological Risks of Alcohol Mixed with Energy Drinks

The combination of alcohol and energy drinks is associated with a range of physiological effects that can exacerbate the risks associated with alcohol consumption alone. These effects, including dehydration, motor coordination impairment, and overstimulation, pose immediate health concerns, particularly in young or active individuals.

A primary risk of AmED consumption is dehydration, as both alcohol and energy drinks have diuretic effects. Dehydration not only worsens hangover symptoms but also, in conjunction with physical exertion, can lead to severe health consequences, including fatal outcomes (Finnegan 2003).

AmED has also been associated with greater impairments in motor coordination than alcohol alone, leading to higher levels of dexterity impairment (Asorey et al. 2018). Research further indicates that AmED consumption accelerates the loss of righting reflex, a sign of deep intoxication, highlighting the amplified physiological effects of this combination (Krahe et al. 2017).

Among adolescents, AmED consumption is linked to both depressive and stimulating side effects. Depressive symptoms include dizziness, headache, fatigue, slurred speech, drowsiness, and reduced coordination, while stimulating symptoms consist of heart palpitations, insomnia, fidgeting, tremors, agitation, sudden energy peaks, rapid speech, and muscle tension (Droste et al. 2017). Survey data supports these findings, showing that AmED consumers experience more pronounced overstimulation symptoms, such as heart palpitations, compared to those who consume alcohol alone. For instance, in an online survey conducted in Australia, respondents reported a range of overstimulation effects during AmED sessions that were not as commonly experienced during alcohol-only sessions (Peacock et al. 2012).

Long-Term Physiological Risks of Alcohol Mixed with Energy Drinks

The long-term effects of consuming alcohol mixed with energy drinks raise significant concerns regarding physical and mental health, as well as the potential risk of addiction.

1. **Risk of arrhythmias and potential cardiovascular changes: S**everal studies highlight a troubling correlation between the concurrent intake of energy drinks (EDs) and alcohol among young adults, with notable adverse implications for cardiovascular health. Research indicates a pattern of severe cardiovascular events—including arrhythmias, coronary artery disease, and even fatalities—that disproportionately impact young males. Although the exact mechanisms behind these outcomes are not yet fully understood, factors such as dehydration, electrolyte imbalances, conflicting autonomic nervous system responses, and impaired judgment are likely contributors (Azarm et al. 2024).

2. **Effects on mental health and neurological systems:** Another research demonstrates that the simultaneous consumption of alcohol and energy drinks triggers oxidative stress and an inflammatory response within the hippocampus and temporal cortex in rats. This combination has the potential to intensify harm to brain regions critical for memory, learning, and emotional regulation. (Díaz et al. 2016).

3. **Other organ-related impacts:** Furthermore, oxidative imbalance was identified in the kidneys after 24 hours of exposure to energy drinks and their components, caffeine and taurine. When energy drinks were combined with alcohol, there was evidence of potential transient nephrotoxicity. Mild histopathological changes were also noted in the liver. These findings highlight the need for a more thorough safety assessment of alcohol and energy drink combinations, particularly in adolescents, who are the primary consumers of these products. (Costa-Valle et al. 2018).

4. **Association with potential addiction:** Frequent consumption of energy drinks has been shown to drive alcohol consumption and increase the risk of alcohol dependence, as suggested by a survey conducted in Taiwan, where AmED consumers were found to be more dependent on alcohol compared to those who consume liquor alone [(American Psychiatric Association 2000) (Cheng et al. 2012)].

As summarized in Table 2, the consumption of AmED is associated with a wide range of behavioral, physiological, and addiction-related consequences, highlighting the multidimensional risks posed by this combination.

Table 2. Behavioral, physiological and addiction-related consequences of AmED

Category	Risk/Effects
Behavioral Risks	Reduced awareness of intoxication and heightened stimulation
	Increased urge to consume more alcohol
	Encourages binge drinking and risky sexual behavior
	Greater likelihood of using other substances
	Higher probability of injuries or medical emergencies
	Increased tendency to drive under the influence
	Risk of aggression, particularly in individuals with poor impulse control
Short-Term Physiological Risks	Dehydration due to diuretic effects
	Motor coordination impairments
	Overstimulation (e.g., heart palpitations, insomnia, tremors)
	Accelerated deep intoxication effects (loss of righting reflex)
Long-Term Physiological Risks	Cardiovascular problems (e.g., arrhythmias, coronary artery disease)
	Neurological damage due to oxidative stress and inflammation
	Kidney and liver damage
Addiction Potential	Increased risk of alcohol dependence with frequent AmED consumption

Final Remarks

The consumption of Alcohol Mixed with Energy Drinks poses serious health risks, particularly among young adults. The combination of caffeine and alcohol leads to increased alcohol intake, a false sense of sobriety, and engagement in high-risk behaviors. These effects contribute to a greater likelihood of alcohol dependence, cardiovascular, neurological and kidney disturbances, and impaired decision-making.

Despite regulatory efforts, AmED remains widely consumed, often outside the scope of legal restrictions. Given its growing prevalence, public health policies should focus on stricter regulations, targeted educational campaigns, and better consumer awareness to mitigate its risks. Future research should aim to clarify the long-term physiological and behavioral consequences of AmED consumption and assess the effectiveness of intervention strategies.

Author's contribution

All authors contributed to the article. Conceptualization, Zuzanna Cisowska, and Martyna Zdych; methodology, Zuzanna Cisowska, and Dr Dagmara Gaweł-Dąbrowska; check, Zuzanna Cisowska, and Dr Dagmara Gaweł-Dąbrowska; formal analysis, Zuzanna Cisowska, Martyna Zdych, Patrycja Chudzik, Maksym Bodziony, Andrzej Terebus; writing - rough preparation, Zuzanna Cisowska, Martyna Zdych, Patrycja Chudzik, Maksym Bodziony, Andrzej Terebus; writing - review and editing, Zuzanna Cisowska, Martyna Zdych, Dr Dagmara Gaweł-Dąbrowska; visualization, Zuzanna Cisowska, Martyna Zdych, Patrycja Chudzik; supervision, Dr Dagmara Gaweł-Dąbrowska; All authors have read and agreed with the published version of the manuscript.

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