

Can Energy Drinks Increase the Desire for More Alcohol?^{1–4}

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ABSTRACT

Energy drinks, the fastest growing segment in the beverage market, have become popular mixers with alcohol. The emerging research examining the use of alcohol mixed with energy drinks (AmEDs) indicates that the combination of caffeine-containing energy drinks with alcohol may be riskier than the use of alcohol alone. The public health concerns arising from AmED use are documented in different research domains. Epidemiologic studies reveal that the consumption of AmEDs is frequent among young and underage drinkers, demographic groups that are more likely to experience the harms and hazards associated with alcohol use. In addition, for all consumers, elevated rates of binge drinking and risk of alcohol dependence have been associated with AmED use when compared to alcohol alone. Results from laboratory studies help explain why AmED use is associated with excessive intake of alcohol. When an energy drink (or caffeine) is combined with alcohol, the desire (or urge) to drink more alcohol is more pronounced in both humans and animals than with the same dose of alcohol alone. The experience of drinking alcohol appears to be more rewarding when combined with energy drinks. Given that caffeine in other foods and beverages increases preference for those products, further research on AmEDs may elucidate the underlying mechanisms that contribute to alcohol dependence. *Adv Nutr* 2015;6:96–101.

Keywords: alcohol, energy drinks, caffeine, motivation, reward, preference, desire, dependence

Introduction

Caffeine-containing energy drinks are popular and controversial new consumer products. Energy drinks vary in typical ingredients but most are sweetened carbonated beverages containing high amounts of caffeine and other ingredients, including taurine, guarana, ginseng, glucuronolactone, and vitamins (1–3). Part of the controversy surrounding the consumption of energy drinks is their popularity mixed with alcohol. The use of alcohol mixed with energy drinks (AmEDs) is common in bars, where consumption of variations of AmED cocktails includes options such as a vodka Red Bull (Red Bull GmbH) or a Jagerbomb (Mast-Jagermeister SE) (a shot of Jägermeister placed in a pint glass filled with an energy drink) (4). Even when alcohol is consumed alone, there

are both immediate and long-term health risks, but those risks appear to be elevated further with AmEDs (5).

The immediate risks of binge drinking and alcohol poisoning associated with AmED use were first identified ~5 y ago when premixed AmED products were available in the United States (6, 7). Premixed caffeinated alcoholic beverages were available from several companies, including brands such as Four Loko, Moonshot, Sparks, B-to-the-E, and Joose. Many underage and young adult drinkers were admitted to emergency rooms with high blood alcohol concentrations after reportedly consuming these products (7). These medical cases prompted physicians and scientists to raise concerns about the safety of these relatively new alcoholic beverages. In November 2010, health and safety concerns associated with the use of premixed AmED products led the USFDA to review the available scientific evidence on the topic. It appeared that the combination of the high amounts of caffeine found in energy drinks with alcohol might lead consumers to misperceive their level of intoxication, thus leading to overdrinking and resulting in accidents and injuries. The FDA determined that caffeine was an unsafe food additive when combined with alcohol (8–10). Manufacturers of the premixed AmED beverages did not dispute this claim and voluntarily removed the stimulant ingredients from their alcohol products.

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Although premixed AmED products have not been available in the US marketplace since late 2010, bartenders and consumers continue to mix their own AmED beverages. The surprising trend is that consumption of AmEDs continues to increase, particularly among younger individuals (11–13). Current AmED beverages (packaged separately but mixed for consumption) are pharmacologically equivalent to the products that were previously available premixed on store shelves. The growing and widespread appeal of AmEDs prompts the question: why? What is the appeal of AmEDs to consumers? It is unlikely that consumers choose AmED beverages in order to misperceive their level of intoxication, although such misperception could result from consumption of AmEDs. There are several possibilities that could explain the growing appeal of AmEDs, including the effective marketing of these beverages to appropriate target audiences or experiences of consumers that energy drink use can mitigate some alcohol-induced sedation (4). However, one alternative explanation, which is the focus of this article, is that drinking alcohol is experienced as more rewarding when the alcohol is combined with energy drinks. On the basis of the growing scientific evidence reviewed below, several studies from different laboratories now demonstrate that the experience of drinking alcohol is more positive and rewarding when an energy drink is used as a mixer (14–17). Although this body of literature is small, the results are concerning because increased urges to drink more alcohol can be problematic immediately (e.g., risk of alcohol poisoning during a single drinking episode) and in the long-term (e.g., development of an alcohol dependence problem). Moreover, it may not be surprising that energy drinks increase the appeal of alcohol, given what has been learned from the broader literature. Caffeine (the primary psychoactive stimulant in energy drinks) is known to increase the preference for a variety of beverages and foods (18, 19).

Current Status of Knowledge

Health and safety concerns regarding the use of AmED beverages are growing, particularly among underage and young adult consumers, on the basis of research findings using diverse methodologies. First, the systematic tracking of adverse consequences associated with AmED use provides objective data to substantiate these concerns. The Drug Abuse Warning Network, a public health surveillance system in the United States, has identified a dramatic increase in negative medical outcomes associated with energy drink use (alone and combined with alcohol). There have been substantial increases in the number of emergency department visits in the United States related to the use of energy drinks, with a large subset of those visits involving AmEDs (20, 21). Likewise, phone calls to US poison control centers related to energy drink use revealed serious health risks associated with energy drink use in combination with alcohol. Data from 2010 to 2011 from the US National Poison Data System revealed that 11% of energy drink calls also involved alcohol. Importantly, 68% of the AmED cases were underage drinkers. Finally, ~77% of AmED

phone calls resulted in a referral to a health care facility, whereas only 26% of energy drink-alone calls required such a referral (22). The literature lacks detail regarding the status and seriousness of the medical conditions of patients arriving at a hospital who need care after consumption of AmEDs. However, one small case series analysis of individuals presenting to the emergency department who were intoxicated after consuming AmEDs revealed that more than one-third of these patients had blood alcohol concentrations >0.16 g% (i.e., double the legal limit for driving in the United States) (7). Hospital admissions were primarily for symptoms of unconsciousness or altered mental state. In sum, the burden placed on the health care system from energy drink use is often the result of energy drinks being mixed with alcohol.

Second, the public health risks associated with the use of AmEDs go beyond the direct burden to emergency departments and hospitals from AmED consumers. Results from US field research revealed that bar patrons who had consumed AmEDs were at a 3-fold increased risk of leaving the bar legally intoxicated and at a 4-fold increased risk of reporting an intention to drive home while intoxicated compared with other drinking patrons (23). Similar results were observed with AmED consumers in European drinking establishments (24), although one Dutch on-premise study did not find that drinking differed for AmEDs and alcohol-alone occasions in the same individuals using a within-subjects design (25). Other survey research has tracked individual drinking behavior over time by using a within-subjects design and found that alcohol intake was higher on days when alcohol was combined with energy drinks (26). An additional burden is placed on law enforcement when more bar patrons are intoxicated, which appears to be more common when AmEDs are consumed.

A third health and safety concern associated with AmED beverages is that they are particularly likely to be consumed by young (often underage) drinkers (11, 12, 27, 28). Given that novice drinkers are already prone to experience the harms and hazards associated with alcohol use, the appeal of AmEDs may be of particular concern in this vulnerable population. The lack of experience with alcohol will contribute to a failure to keep alcohol intake within a safe range and thus lead to accidents and injuries. Excessive alcohol intake is particularly problematic for the adolescent brain, which is still undergoing structural development. The ongoing development in the adolescent brain makes it uniquely sensitive to the neurotoxic effects of alcohol. It is now becoming clear from both human and animal research that even as little as one or a few binge doses of alcohol in an adolescent can cause long-lasting or even permanent brain damage, even though the same dose of alcohol may be relatively innocuous in an adult (29–34).

It remains unknown why AmED beverages are appealing to underage drinkers, although the appeal may be pharmacologic. Novice drinkers are more likely to self-report greater sedation than are experienced drinkers when given a dose of alcohol (35, 36). In controlled laboratory studies using social drinkers, AmED consumption led to greater

self-reported stimulation and less sedation than did alcohol alone (37–41). Greater stimulant effects after alcohol and caffeine consumption (compared to alcohol alone) are also reliably observed in animal models (42–45). Stimulant effects are known to contribute to within-session drinking behavior and are reported as a positive aspect of social drinking in our culture (46). Thus, energy drinks may be particularly appealing to young drinkers because consumption of AmED beverages results in less subjective sedation than do other types of alcohol.

The last health and safety concern regarding AmEDs is that the heavy drinking that accompanies AmED use in all consumers may have long-term implications for the risk of addiction. Two studies revealed that consumers of AmEDs are more likely to screen positive for alcohol dependence (16, 47). It is still very unclear whether AmED use results in more exposure to alcohol in general or directly contributes to dependence risk by changing the subjective experience with alcohol. At least one animal study suggests that the subjective experience is altered directly by the energy drink, heightening the risk of alcohol problems, even when the amount of alcohol is held constant (44). All of the above evidence suggests that consumers may drink more alcohol when it is mixed with an energy drink. Greater alcohol intake when energy drinks are mixers may ultimately lead to a disorder, in which controlling alcohol intake becomes difficult within an individual drinking episode and then repeatedly across multiple drinking episodes. However, there is some lack of control of extraneous variables in the epidemiologic studies and field research described above. Consumers of AmEDs choose these beverages. AmED consumers may differ from alcohol-alone consumers on a variety of characteristics, such as personality traits like a propensity for risk-taking (48, 49) or a genetic predisposition for developing an alcohol dependence problem. Therefore, controlled laboratory studies provide helpful information in determining if AmED beverage consumption leads to greater alcohol intake when compared to alcohol alone. These studies help determine if AmEDs present a unique risk beyond that of alcohol alone, even when the individual consuming the beverage is held constant.

Laboratory studies have examined whether AmEDs vs. alcohol alone differ in how they lead to motivation to drink alcohol. Reports from both human and animal studies reveal that the desire to drink (or actual drinking) is elevated for AmEDs vs. alcohol alone. In human studies, a priming model clarified the processes involved in the motivation to drink alcohol. It is known that the consumption of a moderate (e.g., 1 or 2 standard alcoholic drinks) dose of alcohol can reinforce or “prime” continued drinking during one episode, a factor that contributes to binge drinking (46, 50, 51). In simple terms, control over one’s drinking is easy when completely sober, whereas behavioral control decreases significantly starting at the first drink or 2. The consumption of a moderate dose of AmEDs (or caffeine in alcohol) enhances alcohol priming (as measured by increased desire-to-drink-more-alcohol ratings that last for a longer duration of time) vs. a similar dose of alcohol alone (14, 15, 17).

Given that blood alcohol concentrations do not differ for AmEDs vs. alcohol alone (when the mixer is equivalent), the enhanced desire to drink alcohol results from the energy drink elevating the rewarding properties of alcohol for a longer time. The observations from these studies, which come from 3 laboratories (including one study from our own laboratory), coincide with the findings that consumers of AmEDs are more likely to engage in binge drinking in real-world settings (23). Our initial report (14) was considered controversial, prompting calls for replication and extension (52–54). Thus, this area is not without controversy and more work is clearly needed. However, self-reported desire-for-drug ratings are known to reliably correlate with actual consumption among social drinkers (55). It seems logical to conclude that a laboratory-based demonstration will show that individuals will consume more AmEDs than alcohol alone, but a study that demonstrates this is not yet available. Despite the gap in the human literature, there are similar studies in the animal literature that directly address this same question by measuring actual drinking behavior.

Similar to the human studies, results from 3 laboratories have demonstrated that 5-mg/kg doses of caffeine (similar to human consumption of energy drink mixers) increases the consumption of alcohol in ad lib administration models using rats (56–58). The dose effect for caffeine enhancing alcohol consumption appears to be biphasic in nature. Caffeine doses of ≥ 10 mg/kg result in decreased alcohol consumption in rodents (42, 57, 58). It appears that less is more when examining if caffeine can enhance the desire to drink more alcohol in animal models. The higher doses of caffeine may not lead to greater drinking for 2 reasons. First, caffeine is a bitter-tasting alkaloid. This bitterness is likely aversive to rodents, especially when caffeine doses are higher. If this bitterness were to be masked by a sweet taste (similar to a typical energy drink), caffeine could lead to greater drinking in rodents. However, animal researchers are reluctant to include sucrose in their ad libitum administration studies because sucrose alone is very rewarding for rodents. To complicate matters a bit further, some researchers found that rodents will consume solutions that include caffeine even when no sweetener is used (42). However, it should be noted that humans always consume alcohol with caffeine in a sweetened form (either as an energy drink or a soft drink). As such, it would be helpful if animal researchers would replicate human behavior in rodents to better understand the combined effect of alcohol and energy drinks. A second reason that higher doses of caffeine may not be found to elevate alcohol drinking in animal models is that aversive effects from caffeine may be experienced by rodents at higher caffeine doses. In humans, symptoms of caffeine intoxication (e.g., jitteriness, heart palpitations) are typically not harmful, but they are aversive and are experienced at excessive amounts of caffeine intake (59). Because these symptoms are challenging to assess in rodents, it remains unknown if they are important factors to caffeine aversion. Despite these complications (that may be resolved with future

research), there does appear to be evidence from animal studies that caffeine elevates the desire to drink alcohol. The combined results from human and animal studies would thus far suggest that consumption of AmEDs leads to greater drinking of alcohol than the consumption of alcohol alone.

The growing, albeit still small, literature suggests that energy drinks mixed with alcohol appear to increase the appeal of alcohol. This leads to risks both immediate and long-term for the consumer. Controlling one's intake of alcohol to keep consumption within a safe range (i.e., below an intoxicating dose) seems to be more challenging when energy drinks are used as a mixer. While addiction researchers grapple with the scope of how risky AmEDs are to consumers, an interesting broader question emerges. Is alcohol unique? As mentioned earlier, caffeine (the primary psychoactive stimulant in energy drinks) is known to increase the preference for a variety of beverages and foods. For example, when participants repeatedly tasted a novel drink flavor containing caffeine, their ratings of pleasantness of the flavor increased in a progressive fashion (18, 60, 61). This phenomenon extends beyond beverages to other foods. In another study, participants increasingly liked a novel flavored yogurt more over time when it was paired with caffeine vs. a placebo (19). The appeal of foods and beverages that contain caffeine does not appear to be due to flavor enhancement (62). Regular cola soft drink consumers cannot detect the effect of the caffeine concentration in most cola-type soft drinks. Moreover, preference for caffeinated beverages develops over time, suggesting that consumers learn to pair the mood-enhancing effects of caffeine with the novel beverage. This learning leads to a change in preference for the caffeinated beverage. Therefore, alcohol may not be unique in how energy drinks (or caffeine) enhance the preference for alcohol, because the same phenomenon is also observed with other beverages and foods.

What may be unique with the combination of energy drinks and alcohol is a potential direct central nervous system interaction between caffeine and alcohol. The sedation experienced when drinking alcohol occurs because of increased extracellular activity of the neurotransmitter adenosine in the brain (63–65). Adenosine is an inhibitory neurotransmitter that increases sedation and contributes to sleep under normal conditions. Caffeine blocks the action of adenosine, thus increasing wakefulness (66). This action explains why consumers of caffeine experience the most pronounced change in alertness after caffeine use when their baseline states are sedated. Alcohol research has now established that caffeine interacts with the adenosine neurotransmitter system that underlies alcohol-induced sedation (67–69). The self-administration of alcohol is also regulated by adenosine activity, such that high levels of adenosine activity curb alcohol consumption (67, 69). Because caffeine opposes the action of adenosine, continued alcohol consumption is expected when caffeine is also on board. Continued alcohol consumption when adenosine activity is suppressed by caffeine may also be mediated by elevations in activity of

the neurotransmitter dopamine. Elevated dopamine concentrations play a key role in the abuse potential of most drugs of abuse, including alcohol, because dopamine activity is rewarding. The activation of adenosine receptors inhibits dopamine activity (70). Because caffeine acts as an adenosine receptor antagonist, caffeine blocks adenosine activity, resulting in increased dopamine activity (63, 69, 71). The changes in the activity levels of adenosine and dopamine in the brain suggest that the combined effects of alcohol and energy drinks may be uniquely risky, even as caffeine may generally increase the preference for a variety of foods and beverages.

Conclusions

Caffeine-containing energy drinks are controversial new consumer products in part because they are frequently mixed with alcohol. The immediate and long-term risks associated with the the consumption of alcohol appear to be further elevated with AmEDs. These risks include binge drinking, alcohol poisoning, and the need for medical treatment related to drinking alcohol. Researchers examining AmED use have largely argued that their use is risky because consumers misperceive their level of intoxication, which contributes to accidents and injuries while drinking. However, the growing and compelling evidence from human and animal studies suggests that the increased desire to drink alcohol when consumed as AmEDs may be more central to why AmEDs are risky. The excessive use of alcohol can result in both immediate risks (e.g., alcohol poisoning) and long-term problems (e.g., development of an alcohol dependence disorder). Keeping alcohol consumption within a moderate range appears to be more challenging for consumers when energy drinks are used as mixers. The appeal of AmEDs to underage drinkers seems particularly concerning given that this demographic group is inexperienced with drinking alcohol and will have difficulty keeping alcoholic intake in a moderate range. In addition, the adolescent brain is still undergoing structural development, which makes it uniquely sensitive to the neurotoxic effects of alcohol.

Future research is needed to better understand the extent to which energy drinks elevate the desire to drink alcohol. A clear gap in the literature is an ad libitum administration study in humans comparing AmEDs with alcohol alone. On the basis of animal research, it is predicted that given free access to similar-tasting beverages, participants will consume more AmEDs than alcohol alone. Finally, more research is needed to better understand why consumers prefer and consume more foods and beverages that contain caffeine. Given the findings from the AmED literature, it is possible that greater consumption of all foods and beverages may occur when caffeine is present. Given the dramatic escalation in the use of higher doses of caffeine in a wide variety of consumer products, including energy drinks, it would be important to understand if greater food consumption is occurring as a result. In a society grappling with how best to address a growing obesity problem, more knowledge about the extent to which caffeine in foods and beverages leads to greater use of these products is needed.

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