

Alcohol Mixed With Energy Drinks and Risk of Injury: A Systematic Review

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ABSTRACT. Objective: The present study is a systematic review of the literature examining the relationship between alcohol mixed with energy drinks (AmED) and injury. The study provides a summary and critical analysis of the current literature. **Method:** The review was conducted using PRISMA guidelines for systematic reviews. Studies included in the review were those that quantified the relationship between AmED use and injury risk relative to alcohol only. Records were considered along the following theme areas: controlled for drinking behaviors, controlled for impulsivity or risk-taking propensity, examined sex differences, and self-reported injury outcomes for (a) AmED versus alcohol consumers and (b) AmED versus alcohol sessions. **Results:** The results support the

association between AmED and increased risk of injury; however, substantial variability in harm outcomes and methodology makes it difficult to determine the extent of this risk. **Conclusions:** There is significant need for further examination of the role of AmED use in the risk of injury. A better understanding of the relationship between AmED use and injury and of the potential underlying mechanisms is crucial for informing effective preventive intervention strategies. This review can be used to inform the public and health practitioners of the risks associated with AmED use. Further, translating this knowledge to policy makers could inform regulations on the availability of AmED, with the goal of reducing injury-related outcomes. (*J. Stud. Alcohol Drugs*, 78, 000–000, 2017)

THERE HAS BEEN A TREND in recent years toward increased use of alcohol mixed with energy drinks (AmED) across North America (Howland et al., 2011). AmED refers to the combining of energy drinks with alcohol, either by hand or in pre-mixed beverages sold in liquor stores. There is evidence of increased risk of both intentional and unintentional injury following AmED use (O'Brien et al., 2008). Injury refers to physical harm or damage to a body, caused unintentionally (e.g., falling, tripping, motor vehicle accident) or intentionally (e.g., violence, suicide). It has been estimated that the number of emergency department visits involving energy drinks nearly doubled between 2007 and 2011, with 13%–16% of these admissions related to AmED use (Center for Behavioral Health Statistics and Quality, 2013). Following several fatal incidents reported in the media involving alcoholic energy drinks, there have been calls from Health Canada and others for more research in this area (Health Canada, 2011; Schmidt, 2011).

The increase in risk of injury related to AmED use is thought to be due to both increased alcohol consumption and a diminished sense of perceived intoxication (Howland et al., 2011). Some researchers have theorized that the stimulant effects of energy drinks may work to attenuate the depressant effects of alcohol, thereby masking the physiological and psychological sedative experiences (Ferreira et al., 2006; Marczynski et al., 2011). This masking of the

sedative effects may result in consumers underestimating their level of intoxication, which has been theorized to lead to more hazardous drinking practices, increased risk-taking, and poorer risk assessment (Brache & Stockwell, 2011; Ferreira et al., 2006). Such behavioral changes caused by AmED consumption are all associated with a higher likelihood of the consumer incurring an injury (Room et al., 2005; World Health Organization, 2009)

However, there have been mixed findings regarding the ability for energy drinks to attenuate the negative effects of alcohol, with impairment of some psychomotor functions but not others (Marczynski & Fillmore, 2006). In addition, some research suggests that AmED use may produce subjective effects, such as a reduction in subjects' perception of intoxication, without reducing blood alcohol level or related psychomotor deficits (Ferreira et al., 2006). Therefore, some negative effects of alcohol intoxication may be attenuated when mixed with caffeinated drinks, but overall impairment still exists.

To the best of our knowledge, the present study is the first systematic review of published research on AmED use and risk of injury. With many countries currently determining the level of need and suitability of policy responses to energy drinks and AmED use, it is crucial that we begin to integrate and further our understanding of the current literature. Although our primary objective of this article is to review evidence for whether AmED use compared with alcohol use alone is associated with increased injury risk, we also investigate specific variables that have been indicated as risk factors for alcohol-related injuries.

In particular, risk-taking tendency and binge drinking have been associated with a higher risk of experiencing alcohol-related consequences (Brache & Stockwell, 2011;

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Igra & Irwin, 1996); therefore, these variables may also be associated with a higher likelihood of experiencing negative outcomes following AmED consumption. Individuals scoring higher in sensation seeking might show preference for the “awake drunk” state of AmED use and, therefore, may be more likely to engage in AmED use (O’Brien et al., 2013).

Research also indicates that individuals who tend to consume more alcohol or engage in more binge drinking may be more likely to engage in risky drinking behaviors and have greater opportunity to experience harms related to risky drinking behaviors (Brache & Stockwell, 2011; O’Brien et al., 2013). Therefore, controlling for such factors becomes important when trying to isolate the effects of AmED use on AmED-related injury. As such, the current article examines whether the literature on AmED use and injury has identified any associations that may parallel the findings of alcohol-related injury research. Last, the article explores whether there are any sex differences underlying this association, as some studies suggest that sex differences exist in the risk relationship between alcohol use and injury (McLeod et al., 1999; Nordstrom et al., 2001).

Method

Search strategy

An appendix that accompanies the online version of this article details the study selection and data extraction process (Appendix 1), and the research protocol is registered on PROSPERO (Roemer et al., 2016). Studies were identified by author A.R. via EBSCO and Pubmed (last search 15 February 2016). Each energy drink-related search term (“energy drink*”; “Red Bull”) was combined with all alcohol search terms (“alcohol*”; “drinking*”) in conjunction with the following: “injury*”; “harm*”; “adverse effect*”; “adverse outcome*”; “risk*”; or “accident*.” An additional search term of “caffeinated* alcohol” was included in the search. All duplicates were removed and the first author (A.R.) completed initial eligibility screening based on publication criteria. Content assessment based on title and abstract was performed by the first author. The assessment was not blind, with full-text review when necessary. A secondary reviewer examined selected articles and randomly reviewed excluded articles for accuracy and consistency in search strategy.

Publication criteria

Studies were restricted to those that quantified the risk relationship between combining alcohol and energy drinks with the risk of an injury-related outcome of some kind. Animal studies, case studies, qualitative studies, reviews, methodology articles, and commentaries were excluded. Peer-reviewed journal articles published in English between

January 1981 and January 2016 with the search terms in the title or abstract were included.

Content criteria

Because the primary objective of the review was to examine the association between AmED use and injury relative to alcohol alone, articles were included if they reported comparisons of AmED versus alcohol consumers or AmED versus alcohol consumption with regard to the incidence of an intentional or unintentional harm or injury outcome. AmED use refers to combining energy drinks with alcohol, either by hand or in pre-mixed beverages. Alcohol combined with energy drinks by hand was defined as either combining both beverages into a single beverage to consume simultaneously or consuming both beverages consecutively within the same drinking session.

Articles were included only if they specifically measured the occurrence of being either intentionally or unintentionally hurt or injured. Studies that examined other, or broader, alcohol-related outcomes (e.g., sleep, academic difficulties) or risk-taking behaviors only (e.g., driving under the influence) were excluded.

Data extraction and analysis

A data extraction sheet was used to extract information on study design, sample characteristics, primary measures, method of administration, covariates, and outcomes. A second researcher reviewed the data extraction for quality assurance. The reviewers were not blind to the publication details. Although no studies were removed based on quality assessment, study quality was considered in the synthesis of the results. Specifically, included articles were coded for whether they controlled for drinking behaviors, controlled for personality traits of impulsivity or risk-taking propensity, examined sex differences, and used self-reported injury outcomes both for (a) AmED versus alcohol consumers and (b) AmED versus alcohol sessions. Although we considered running a meta-analysis because this is often the next step following a systematic review, it was decided that, with such a small sample size and the large degree of heterogeneity in measures and outcomes, this would not be meaningful.

Results

Sample for synthesis

A total of 323 articles were retrieved after duplicates were removed (Figure 1). Thirteen studies were included in the final sample following exclusion (Table 1). For ease of identifying the included studies and reporting results, each study was assigned a number. The numbers in brackets in the following refer to the number of the study as per Table

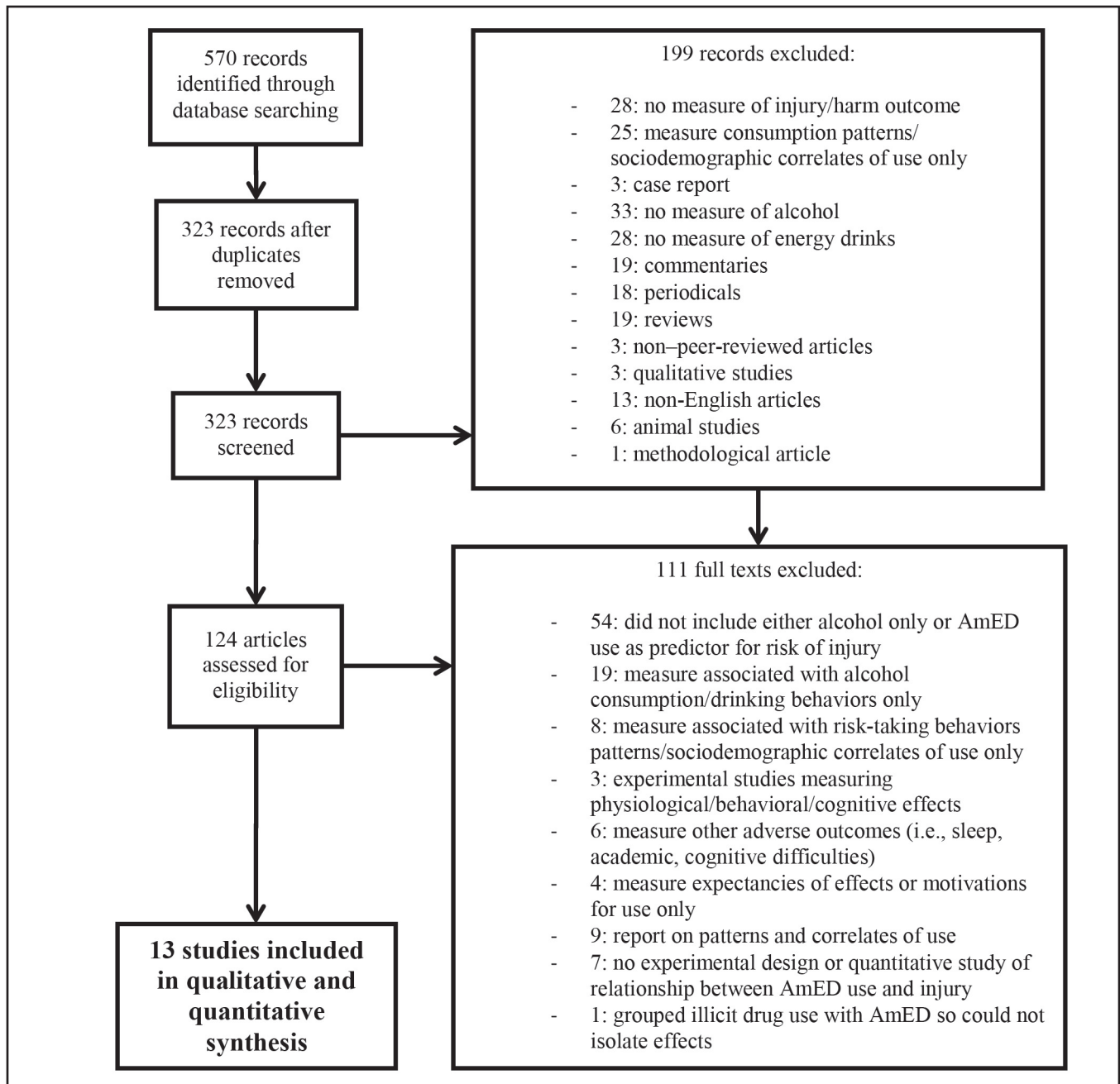


Figure 1. Search strategy for selection of studies. AmED = alcohol mixed with energy drinks.

1. The majority of studies were from the United States ($n = 8$), two were Canadian, one was from Australia, one had samples from Australia and New Zealand, and one was from Taiwan. Six studies sampled college or university students, three used general population samples [8, 9, 12], two used high school students [1, 6], one used manual workers [4], and one used active military personnel [7]. All were cross-sectional studies, of which three used within-subject designs [2, 8, 9] and the remainder a between-subjects design.

Definition of injury/harm, alcohol, and alcohol mixed with energy drinks use

All 13 studies reported risk estimates for AmED use and an injury or harm outcome. Although all but two articles measured the presence of harm or injury as a dichotomous outcome, there was variability in the definition of the injury or harm outcome: Six studies defined the outcome as the occurrence of being hurt or injured [2, 4, 5, 8, 9, 10], three measured the occurrence of being hurt

Table 1. Summary of studies included in the systematic review

Study	Study design	Sample n and characteristics	Definition of AmED use	Definition of harm outcome	Covariates	Results (risk estimate)
1. Martz et al., 2015	Cross-sectional descriptive	Grade 12 U.S. students, randomized sample ($n = 3,169$ males). Total $N = 6,498$; AmED users = 1,600.	Simultaneous use in past 12 months (frequency of use—no. of occasions)	Frequency of MVAs in past 12 months that occurred after drinking alcohol	Sociodemographic groups, social and academic factors, other substance use, binge drinking	Males > AmED use. AmED use associated with > alcohol-related unsafe driving. AmED use in past 12 months associated with > risk of MVAs after drinking (OR = 4.32, 95% CI [1.27, 4.66]).
2. Berger et al., 2013	Cross-sectional descriptive (web-based and interview)	U.S. university students ages 18–25 ($M_{\text{age}} = 21.5$, $SD = 1.7$). 61.6% female, 81.8% White. Total $N = 606$. AmED users = 322; alcohol = 284 (divided into hazardous users $n = 74$ and nonhazardous users $n = 210$).	Past-year AmED use (premixed and self-mixed simultaneous use) (frequency of use)	Past-year report of being hurt/injured because of alcohol (dichotomous)	None reported	Nonhazardous drinkers significantly < likely to drive car under influence, be hurt/injured, or have unprotected sex. No sig. differences found between hazardous drinkers who drink AmED and non-AmED hazardous drinkers in injury (OR = 1.92, 95% CI [0.90, 4.10]). Males > likely to be injured overall. No sex differences in AmED use.
3. O'Brien et al., 2008	Cross-sectional descriptive (web-based)	U.S. undergraduate college students ($M_{\text{age}} = 20.4$ ($SD = 2.8$), 78% White. Total $N = 4,237$, nondrinkers = 1,351, non-AmED drinkers = 2,189, AmED drinkers = 697).	Simultaneous use in past 30 days (frequency of use)	Been hurt/injured or requiring medical treatment in past 30 days as result of their drinking (yes/no response)	Drinking behaviors (alcohol quantity, binge drinking), sex, age, race, fraternity/sorority status, athlete status, within campus clustering	AmED drinkers drank more during typical drinking session, reported more drinking days and more episodes of weekly drunkenness. AmED users > likely to report being taken advantage of sexually, take advantage of other sexually, ride with driver under influence, be hurt/injured (being hurt/injured: OR = 2.25, 95% CI [1.70, 2.96]; require medical treatment: OR = 2.17, 95% CI [1.24, 3.80]). No sex differences in AmED use.
4. Cheng et al., 2015	Cross-sectional descriptive (in-person survey)	Manual workers in Taiwan ages 25–65 ($M_{\text{age}} = 42.4$, $SD = 9.3$). Male = 1,143. All regular drinkers (drink > 1 per week). Total $N = 11,192$, problem drinkers = 633, AmED drinkers = 411.	Simultaneous use. AmED use more than 1 per week = AmED drinker.	Report of injury or disease because of their work in past year (yes/no response)	Presence of problem drinking (CAGE scores) and alcohol use frequency	AmED users > risk of work-related injury or disease in past year relative to alcohol users only (OR = 1.48, 95% CI [1.14, 1.93]). No sex differences in use or injury.
5. Brache et al., 2011	Cross-sectional descriptive (web-based survey)	Western Canadian university students ages 17–51 ($M_{\text{age}} = 24.03$, $SD = 6.7$), 55.9% female. Total $N = 465$, reported drinking at least once in past 30 days = 410, AmED users = 105.	Simultaneous use of premixed and manually mixed drinks in past 30 days (frequency of use)	Lifetime experience of injury/being hurt with AmED use (dichotomous)	Risk-taking tendency, age, sex, drinking behavior	AmED users > likely to be younger, live on campus, score higher in risk-taking. No sex differences. AmED users > likely to drink larger amounts of alcohol and engage in higher risk drinking practices. More frequent use of AmED in past 30 days associated with being hurt/injured (OR 1.38, 95% CI [1.02, 1.88]). No sex differences.
6. Ilie et al., 2015	Cross-sectional descriptive (school-based survey)	Ontario students (grades 7–12) ages 11–20, 54.9% female. $N = 10,272$ (only $n = 4,794$ asked about AmED use). AmED lifetime users = 3,309.	Simultaneous use in past 12 months (frequency of use)	TBI in past 12 months and lifetime (yes/no); post-12-month occurrence was asked about cause of injury	Academic performance, sex	Past-year and lifetime TBI associated with alcohol and ED use. Recent (but not former) TBI incurred while doing something other than sports was associated with use of 5+ AmED drinks in past 7 days (OR = 6.36, 95% CI [1.48, 27.42]). Sex differences not examined.
7. Mash et al., 2014	Cross-sectional descriptive	Active-duty U.S. military soldier, 45% ages 17–25, 85% male, 65% White. Weighted sample $n = 4,999$, 26% reported AmED use.	Simultaneous use in past 30 days (frequency of use)	Suicidity in past year (seriously considered or attempted) (yes/no response)	Average daily ethanol consumption, ED use, age, sex, race, education, marital status, enlistment status	Daily AmED use > likely suicidality after controlling for all variables (OR = 1.99, 95% CI [1.18, 3.35]). Less than daily use was not significantly associated with suicidality in adjusted model. Sex differences not examined.

Table continued

Table 1. Continued

Study	Study design	Sample n and characteristics	Definition of AmED use	Definition of harm outcome	Covariates	Results (risk estimate)
8. Peacock et al., 2015	Cross-sectional (matched frequency) descriptive	3 samples (2 Australia and 1 New Zealand) of general population age 16 or older ($M_{age} = 22.3$, $SD = 3.4$), 66% female. Total $N = 273$ matched frequency of AmED users.	Monthly AmED use. Standard drink = 10 g alcohol and standard ED = 250 ml of approximately 80 mg caffeine (quantity and frequency of use)	Been physically hurt/injured during AmED and alcohol sessions in past 6 months for 2 studies and 12 months for 1 study (dichotomous)	Matched frequency (to control for relative frequency of alcohol and AmED use), avg ED and alcohol intake in AmED sessions, risk-taking behavior during alcohol sessions	Lower odds of risk-taking behavior after AmED versus alcohol only (OR = .72, 95% CI [.57, .92]). Risk-taking in alcohol-only sessions strongest association with risk-taking in AmED sessions. Greater ED intake after AmED consumption associated with > likelihood of harm/injury. Sex differences not examined.
9. Peacock et al., 2012	Cross-sectional descriptive (web-based survey)	Australian sample from general population age 18–35 ($M_{age} = 23.1$, $SD = 3.8$), 61% female. Total $N = 963$, analysis done only on AmED users $n = 403$.	Subsequent and simultaneous use in past 6 months (quantity and frequency of use)	Been physically hurt/injured in past 6 months during both alcohol and AmED sessions (dichotomous)	None reported (within subject design)	In AmED sessions > alcohol and ED consumed; risk of being hurt/injured < during AmED sessions compared with alcohol only (OR = 0.46, 95% CI [0.36, 0.58]). AmED users report < sedation effects, > stimulatory mood states, and < disinhibition. Sex differences not examined.
10. Wooldsey et al., 2015	Cross-sectional descriptive (in-person survey)	U.S. intercollegiate student athletes (257 male and 144 female), $M_{age} = 19.8$. Total $N = 401$, AmED users = 150, alcohol users = 315.	Use over past year (quantity and frequency of use)	Been injured in past year while using alcohol and AmED	—	AmED users consumed > alcohol and had riskier drinking habits versus alcohol users; in AmED sessions AmED users reported < alcohol use versus alcohol-only sessions, but consumed > ED when using alcohol. AmED users reported more risk taking and negative consequences. No difference in report of injury (paired sample t test $d = 0.08$, $t = -1.12$, $p = .266$). Sex differences not examined.
11. Snipes et al., 2014	Cross-sectional descriptive (web-based)	U.S. university students in intro psych course (253 men and 545 women), M_{age} women = 19.1 ($SD = 2.63$) and men = 19.64 ($SD = 3.1$). Total $N = 798$, 14.2% of men and 10.1% of women reported AmED use.	Number of AmED drinks in past month	Sexual victimization—lifetime report (scale 0–4 times)	Drug use, ethnicity, relationship status, year in school, sexuality	Final model, higher use of AmED associated with > likelihood of sexual victimization for men but not women (Men OR = 1.17, 95% CI [1.01, 1.37]; women OR = 1.06, 95% CI [.92, 1.21]). Correlations show relationship between AmED use and physically forced victimization among women. Men reported > AmED use.
12. Kponee et al., 2014	Cross-sectional descriptive (web-based)	General population in U.S. age 13–20 from nationally based study. Total $N = 1,031$; AmED users = 19.6%. Any caffeinated beverage with alcohol use = 52.4% and traditional CAB = 45.6%.	Simultaneous and subsequent use in past 30 days (frequency of use—no. of days)	Alcohol-related injury and injury requiring doctor visit in past 12 months (dichotomous)	Age, sex, race, income, seat belt use.	All CAB users reported > alcohol use and > binge drinking. This was highest among AmED users. Same pattern found for adverse outcomes. Alcohol-related injury (OR = 5.6, 95% CI [3.6, 8.7]); injury requiring doctor (OR = 1.9, 95% CI [8, 4.4]). No sex differences in AmED use.
13. O'Brien et al., 2013	Cross-sectional descriptive (web-based survey)	U.S. college students, 62% female, $M_{age} = 20.5$ ($SD = 2.9$). Total $N = 4,907$, AmED users = 786; 3,390 reported alcohol use once or more in past 30 days.	Yes/no of simultaneous use in past 30 days	Alcohol-related injury requiring medical treatment in past 12 months (dichotomous)	Typical amount of alcohol consumed and sensation seeking	AmED users higher in sensation seeking and more likely to report injury/harm (OR = 1.71, 95% CI [1.23, 2.39]); however, this was even higher among higher scores of sensation seeking. Males > likely to consume AmED.

Notes: AmED = alcohol mixed with energy drinks; MVA = motor vehicle accident; OR = odds ratio; CI = confidence interval; TBI = traumatic brain injury; CAB = caffeinated alcoholic beverage.

or injured requiring medical treatment [3, 12, 13], one measured the frequency of motor vehicle accidents [1], one defined the outcome as a work-related injury or disease [4], one specified the outcome as traumatic brain injury [6], another study specifically measured suicide and self-harm behaviors [7], and another measured the frequency of sexual victimization [11].

In addition, varying methodologies were used to assess both alcohol and AmED use. The time frame for reporting past AmED use ranged from past 30 days to past 12 months, whereas the time frame for self-reported incidence of injury or harm ranged from past 30 days to lifetime. Many of the studies maintained consistency between the recall period of AmED use and incidence of injury or harm; however, six of the studies had different time frames for measuring these variables [4, 5, 7, 11, 12, 13]. In addition, eight of the studies asked only about injury or harm that had occurred while consuming or following the consumption of alcohol. Of the remaining studies, there was no specification that the injury or harm outcome being measured had to be alcohol related. More specifically, one study asked about injury only during AmED sessions [5], one about injury or disease because of work [4], one focused on the occurrence of traumatic brain injuries [6], one asked about past-year suicidality [7], and one examined lifetime report of sexual victimization [11].

With regard to measuring AmED use, seven articles measured the frequency of use [1, 2, 3, 5, 6, 7, 12], three studies measured quantity and frequency of use [8, 9, 10], one measured quantity of use only [11], and two defined AmED users as those self-reporting AmED consumption at least once in a specified period [4, 13]. Furthermore, 10 studies defined AmED use as simultaneous use [1, 2, 3, 4, 5, 6, 7, 10, 11, 13], whereas three studies measured simultaneous and subsequent use [8, 9, 12]. Last, only two studies [8, 9] used a standard drink method to measure the amount of alcohol and energy drinks consumed. In both studies a standard drink of alcohol was considered approximately 10 g and a standard energy drink was defined as one 250-ml can containing approximately 80 mg of caffeine.

AmED use and risk of injury

Of 13 studies, 10 indicated support for an association between increased risk of injury and AmED use, whereas three found no support for such a relationship [2, 9, 10]. No consistent differences in the type of injury or harm outcome measured, methods, or sample characteristics were observed between the 10 positive studies and the 3 negative studies. However, two of the three negative studies used quantity–frequency measures of alcohol and AmED use and were within-subject comparisons [9, 10]. Study 9 found that although participants reported more alcohol and energy drink consumption during AmED sessions relative to alcohol-only

sessions and typical energy drink use, the risk of injury or harm was lower during AmED sessions compared with alcohol sessions. Similarly, Study 10 found that AmED users typically consumed less alcohol during AmED sessions compared with alcohol sessions; however, no significant differences were found between AmED and alcohol-only sessions in the risk of injury.

The similar methodologies of these two studies are of note, as within-subjects research asks a different question than between-subjects research. In particular, the former examines whether the same individual is at higher risk for injury after AmED use relative to alcohol, which allows for tentative inference of causation. In contrast, between-subjects research examines whether individuals who consume AmED are more risky than those who consume only alcohol, which does not allow for any inference of causation.

The contrast between the findings from these two studies and the reported trend of increased risk of harm or injury following AmED use may be explained by such differences in methodology. However, in Study 8, the authors argued that because the relative frequency of AmED use is less than alcohol-only use, there are fewer opportunities for risk behaviors and injuries to occur. Therefore, to accurately compare the risks associated with both patterns of drinking, the differences in the frequency of these occasions need to be considered. Using a matched-frequency design, partial support was found for increased risk following AmED consumption. The results indicated lower odds of engaging in risk behaviors in AmED sessions relative to alcohol sessions. However, greater average energy drink consumption during AmED sessions relative to average energy drink consumption was associated with an increased likelihood of being physically hurt or injured compared with alcohol-only sessions. The authors concluded that higher levels of energy drink consumption might be associated with a higher risk of injury even after controlling for alcohol intake and risk taking.

The third study [2] reporting no support for increased risk of injury with AmED use was distinct in that the analyses compared three types of drinkers: nonhazardous drinkers, hazardous drinkers, and hazardous drinkers who engaged in AmED use. The authors argued that hazardous drinking is a significant risk factor for experiencing alcohol-related harm; therefore, comparing alcohol-related harms across these three categories of drinkers could help determine the extent to which AmED use is associated with injury or harm while controlling for this pattern of alcohol use. The results indicated that nonhazardous drinkers were significantly less likely to report being injured or hurt, whereas no differences were reported between hazardous drinkers and hazardous drinkers who engaged in AmED use. These findings suggest that individuals who are more likely to engage in risky drinking behaviors are at a higher risk for alcohol-related harm regardless of AmED use.

Risk-taking tendency and other individual characteristics

Three of the studies pointed to the importance of considering risk-taking tendency [5] or sensation seeking [13], as well as risk-taking behaviors during alcohol-only sessions [8], when examining the association between AmED and injury. The results of Study 13 indicated that AmED users scored higher in sensation seeking. After we controlled for this variable, AmED use was still related to a higher risk of injury; however, this association was stronger among individuals with higher scores in sensation seeking. Similarly, Study 5 found that AmED use was associated with higher risk-taking tendency, but the relationship between AmED use and injury remained significant after controlling for this variable. Last, the results of Study 8 indicated that amount of variance accounted for in the relationship between AmED and injury increased by about 45% following the inclusion of risk-taking behavior during alcohol sessions. Taken together, the results suggest that although risk-taking is an important factor in predicting AmED-related injury, AmED use appears to contribute to the risk of injury over and above such dispositional characteristics.

Drinking behaviors and other covariates

The majority of studies controlled for binge drinking [1], alcohol consumption [5, 7, 8, 9, 13], or both [3, 4]. A pattern emerged across several studies indicating that AmED users tend to report higher levels of alcohol consumption and binge drinking than non-AmED users. In addition, the results suggested that more alcohol was typically consumed during AmED sessions relative to either alcohol-only sessions or average alcohol consumption. All but one of the eight studies that controlled for alcohol use or binge drinking still found a higher risk of injury following AmED use [9]. In summary, the results suggest that higher levels of alcohol consumption during AmED use as well as AmED use itself may both contribute independently to the higher likelihood of injury or harm.

There were two other control variables included in three of the publications that were notable. Two of the studies controlled for other substance/drug use [1, 11], and one study considered other caffeine use [12]. Because drug use has been found to be a significant predictor for experiencing alcohol-related harms (O'Brien et al., 2008), and stimulant use could have similar effects to caffeine when mixed with alcohol, controlling for drug use seems crucial. Both studies controlling for this variable still found an association between AmED use and injury or harm. With regard to caffeine use, the authors of Study 12 argued that alcohol is often mixed with caffeinated soft drinks and the consumption of these beverages may have similar effects as energy drinks. Therefore, to isolate any effects of AmED use, it is crucial to control for the potential effects of other caffein-

ated beverages. In their study, they compared AmED use with "traditional" forms of mixing alcohol and caffeinated beverages (i.e., soda). The results of their study indicated that AmED use was associated with a higher risk of injury compared with traditional forms of caffeinated alcoholic beverages and noncaffeinated alcoholic beverage use.

Last, only one study [11] examined sex differences in the relationship between AmED use and risk of injury or harm. Study 11 found that AmED consumption was associated with a higher likelihood of sexual victimization only among men, whereas alcohol use on its own was associated with a higher risk of sexual victimization only among women. No other examination of sex differences in the relationship between AmED use and risk of injury was found in the included publications. However, one study reported that men were overall at a higher risk for injury [1], and two studies reported that men were more likely to consume AmED [11, 13].

Discussion

Overall, the results from the systematic review suggest support for a relationship between increased risk of injury and AmED use; however, several limitations in the current literature were noted. First, all of the studies were cross-sectional and no consideration was given to the temporal occurrence of injury relative to AmED use. As such, no firm conclusion regarding causality between AmED use and injury can be drawn.

In addition, some studies did not differentiate between injuries occurring in alcohol-only sessions relative to AmED sessions, making a comparison of the risk of injury between alcohol and AmED use impossible. Although there is strong evidence to support the association between AmED use and risk of injury, future research assessing the temporal relationship between AmED use and injury is needed to determine the causal pathways between AmED consumption and injury. For example, emergency department studies provide opportunity to obtain information on the timing and context of injuries and any substance use that occurred before the injury. Crossover acute dosing and real-time assessment studies may also be useful to further understand the pharmacological effects of AmED and allow for assessment of risk-taking behaviors in situ.

Last, the majority of studies were case-control designs, and previous research suggests that methodological variations assessing alcohol and injury have resulted in a wide variety of risk estimates (Maclure, 1991; Ye et al., 2010). Therefore, future research should explore other methodological designs (e.g. case-crossover) to examine whether injury risk estimates vary for AmED use.

Another limitation relates to the widely varying definitions and measures of the injury/harm outcome, alcohol use, and the recall time frames used. The practice of using

frequency-only measures limits the ability to confidently determine relationships between use and outcomes, as the quantity of alcohol consumed is important in understanding alcohol-related harms (Rehm, 1998). Furthermore, without the use of a standard drink measure, the amount of ethanol consumed is unknown—again, making it difficult to draw conclusions about the dose-response relationship between alcohol use and outcomes.

Similarly, no standard drink measures have been developed for energy drinks or caffeinated beverages, and only two studies measured the actual amount of caffeine consumed during drinking sessions. Energy drinks can vary significantly in their contents, which makes having a standard drink measure or objective measure of caffeine essential in this research. Furthermore, no study considered the ratio of alcoholic beverage to energy drink consumption during AmED sessions (i.e., one energy drink per alcoholic drink vs. one energy drink for every three alcoholic drinks). Last, only one study included other caffeinated beverages in its analysis (Kponee et al., 2014). The practice of mixing alcohol with caffeinated sodas is common, and yet little research has compared the use of AmED to these other caffeinated beverages. As such, the lack of standardized measuring for AmED use and caffeine consumption makes comparisons across individuals and studies difficult; in addition, it identifies a significant gap in the literature with regard to the risk of injury related to AmED use compared with other caffeine consumption. Nonetheless, the research points to increased risk of harm and injury following AmED use, and future research addressing these limitations could further elucidate this relationship.

Other drug use also was a variable that was largely ignored in the current literature. Previous research suggests that there is a synergistic effect between stimulant use (i.e., cocaine) and alcohol use, such that the combined use of these substances results in a much higher risk of injury relative to the use of the substances on their own (Brache & Stockwell, 2011; O'Brien et al., 2008). Research also indicates that individuals higher in risk-taking tendency are more likely to use stimulant drugs (Chambers et al., 2003), a finding that parallels the relationship between risk-taking tendency and AmED use (Brache & Stockwell, 2011). Thus, individuals consuming AmED may be more likely to use other substances; therefore, differentiating the impact of either of these substances on the likelihood of injuries would be difficult without proper measurement. Controlling for other substance use, particularly stimulant use, is another crucial factor in delineating the relationship between AmED use and the risk of injury. In summary, future research using standardized drink measures and controlling for other caffeine consumption and substance use is needed to fill this current gap in the literature.

In addition to being a predictor for AmED and other drug use, impulsivity or risk-taking tendency was identified within

the literature as a potentially important explanatory factor in the relationship between AmED use and injury. Although the results remain mixed in terms of whether impulsivity or risk taking may moderate the relationship between AmED use and injury risk, there is enough evidence to warrant further exploration. Future research is needed to further explore the role of risk-taking tendency in both the likelihood of AmED use and the relationship between AmED use and injury.

Last, one of the secondary goals of the present study was to examine whether any sex differences exist in the relationship between AmED use and injury. Only one study specifically reported on this difference, with the results suggesting some support for sex differences (Snipes et al., 2014). However, it is difficult to draw such a conclusion with the limited research. Given that previous research provides some support for sex differences in the dose-response relationship between alcohol use and injury (McLeod et al., 1999; Stockwell et al., 2002), future research is needed to determine whether this association also exists between AmED use and injury.

The present study is, to our knowledge, the first systematic review of published research on AmED use and risk of injury. The research provides some support for the association between AmED use and increased risk of injury, but the substantial variability in harm outcomes and methodology makes it difficult to determine the extent of this risk. Future research is needed to expand on the current knowledge and respond to the limitations existing within the literature. Increased knowledge and understanding of the relationship between AmED use and injury could be crucial in informing both the public and public health policy. The importance of and urgency for further restrictions on alcoholic energy drinks are partly related to the extent of evidence that they increase risk of injury or harm. Although some policies have already been put in place to limit the sale and availability of these beverages, further understanding of AmED-related risks could facilitate the development of intervention and prevention practices.

References

- Berger, L., Fendrich, M., & Fuhrmann, D. (2013). Alcohol mixed with energy drinks: Are there associated negative consequences beyond hazardous drinking in college students? *Addictive Behaviors, 38*, 2428–2432. doi:10.1016/j.addbeh.2013.04.003
- Brache, K., & Stockwell, T. (2011). Drinking patterns and risk behaviors associated with combined alcohol and energy drink consumption in college drinkers. *Addictive Behaviors, 36*, 1133–1140. doi:10.1016/j.addbeh.2011.07.003
- Center for Behavioral Health Statistics and Quality. (2013, Jan. 10). *The DAWN Report: Update on emergency department visits involving energy drinks: A continuing public health concern*. Retrieved from <http://archive.samhsa.gov/data/2k13/DAWN126/sr126-energy-drinks-use.htm>
- Chambers, R. A., Taylor, J. R., & Potenza, M. N. (2003). Developmental neurocircuitry of motivation in adolescence: A critical period of addiction vulnerability. *American Journal of Psychiatry, 160*, 1041–1052. doi:10.1176/appi.ajp.160.6.1041

- Cheng, W. J., Huang, M. C., Cheng, Y., Chen, C. H., & Chen, C. J. (2015). Consumption of alcoholic energy drinks is associated with work-related injury or disease among manual workers in Taiwan. *Alcohol and Alcoholism*, *50*, 458–462. doi:10.1093/alcalc/agt022
- Ferreira, S. E., de Mello, M. T., Pompéia, S., & de Souza-Formigoni, M. L. (2006). Effects of energy drink ingestion on alcohol intoxication. *Alcoholism: Clinical and Experimental Research*, *30*, 598–605. doi:10.1111/j.1530-0277.2006.00070.x
- Health Canada. (2011). *Canadian alcohol and drug use monitoring survey: Summary of results for 2009*. Retrieved from http://www.hc-sc.gc.ca/hc-ps/drugs-drogues/stat/_2009/summary-sommaire-eng.php
- Howland, J., Rohsenow, D., Calise, T. V., MacKillop, J., & Metrik, J. (2011). Caffeinated alcoholic beverages: An emerging public health problem. *American Journal of Preventive Medicine*, *40*, 268–271. doi:10.1016/j.amepre.2010.10.026
- Igra, V., & Irwin, C. E., Jr. (1996). Theories of adolescent risk-taking behavior. In R. J. DiClemente, W. B. Hansen, & L. E. Ponton (Eds.), *Handbook of adolescent health risk behavior* (pp. 35–51). New York, NY: Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4899-0203-0_3#page-1
- Ilie, G., Boak, A., Mann, R. E., Adlaf, E. M., Hamilton, H., Asbridge, M., . . . Cusimano, M. D. (2015). Energy drinks, alcohol, sports and traumatic brain injuries among adolescents. *PLoS ONE*, *10*, e0135860. doi:10.1371/journal.pone.0135860
- Kponee, K. Z., Siegel, M., & Jernigan, D. H. (2014). The use of caffeinated alcoholic beverages among underage drinkers: Results of a national survey. *Addictive Behaviors*, *39*, 253–258. doi:10.1016/j.addbeh.2013.10.006
- Maclure, M. (1991). The case-crossover design: A method for studying transient effects on the risk of acute events. *American Journal of Epidemiology*, *133*, 144–153.
- Marczinski, C. A., & Fillmore, M. T. (2006). Clubgoers and their trendy cocktails: Implications of mixing caffeine into alcohol on information processing and subjective reports of intoxication. *Experimental and Clinical Psychopharmacology*, *14*, 450–458. doi:10.1037/1064.1297.14.4.450
- Marczinski, C. A., Fillmore, M. T., Bardgett, M. E., & Howard, M. A. (2011). Effects of energy drinks mixed with alcohol on behavioral control: Risks for college students consuming trendy cocktails. *Alcoholism: Clinical and Experimental Research*, *35*, 1282–1292. doi:10.1111/j.1530-0277.2011.01464.x
- Martz, M. E., Patrick, M. E., & Schulenberg, J. E. (2015). Alcohol mixed with energy drink use among U.S. 12th-grade students: Prevalence, correlates, and associations with unsafe driving. *Journal of Adolescent Health*, *56*, 557–563. doi:10.1016/j.jadohealth.2015.01.019
- Mash, H. B. H., Fullerton, C. S., Ramsawh, H. J., Ng, T. H. H., Wang, L., Kessler, R. C., . . . Ursano, R. J. (2014). Risk for suicidal behaviors associated with alcohol and energy drink use in the US Army. *Social Psychiatry and Psychiatric Epidemiology*, *49*, 1379–1387. doi:10.1007/s00127-014-0886-0
- McLeod, R., Stockwell, T., Stevens, M., & Phillips, M. (1999). The relationship between alcohol consumption patterns and injury. *Addiction*, *94*, 1719–1734. doi:10.1046/j.1360-0443.1999.941117199.x
- Nordstrom, D. L., Zwerling, C., Stromquist, A. M., Burmeister, L. F., & Merchant, J. A. (2001). Epidemiology of unintentional adult injury in a rural population. *Journal of Trauma: Injury, Infection, and Critical Care*, *51*, 758–766. doi:10.1097/00005373-200110000-00023
- O'Brien, M. C., McCoy, T. P., Rhodes, S. D., Wagoner, A., & Wolfson, M. (2008). Caffeinated cocktails: Energy drink consumption, high-risk drinking, and alcohol-related consequences among college students. *Academic Emergency Medicine*, *15*, 453–460. doi:10.1111/j.1553-2712.2008.00085.x
- O'Brien, M. C., McCoy, T. P., Egan, K. L., Goldin, S., Rhodes, S. D., & Wolfson, M. (2013). Caffeinated alcohol, sensation seeking, and injury risk. *Journal of Caffeine Research*, *3*, 59–66. doi:10.1089/jcr.2013.0004
- Peacock, A., Bruno, R., & Martin, F. H. (2012). The subjective physiological, psychological, and behavioral risk-taking consequences of alcohol and energy drink co-ingestion. *Alcoholism: Clinical and Experimental Research*, *36*, 2008–2015. doi:10.1111/j.1530-0277.2012.01820.x
- Peacock, A., Droste, N., Pennay, A., Lubman D. I., Miller, P., Newcombe, D., & Bruno R., (2015). Self-reported risk-taking behavior during matched frequency sessions of alcohol versus combined alcohol and energy drinks consumption: Does co-ingestion increase risk-taking? *Alcoholism: Clinical and Experimental Research*, *39*, 911–918. doi:10.1111/acer.12700
- Rehm, J. (1998). Measuring quantity, frequency, and volume of drinking. *Alcoholism: Clinical and Experimental Research*, *22*, Supplement 2, 4s–14s. doi:10.1111/j.1530-0277.1998.tb04368.x
- Roemer, A., Stockwell, T., & Cherpitel, C. (2016). *Alcohol mixed with energy drinks: A systematic review*. PROSPERO 2016: CRD42016039026. Retrieved from http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016039026
- Room, R., Babor, T., & Rehm, J. (2005). Alcohol and public health. *The Lancet*, *365*, 519–530. doi:10.1016/S0140-6736(05)17870-2
- Schmidt, S. (2011, June 13). Health Canada ignored advice to probe alcohol, energy-drink mix. *Winnipeg Free Press*. Retrieved from <http://www.winnipegfreepress.com/canada/health-canada-ignored-advice-to-probe-alcohol-energy-drink-mix-123732954.html>
- Snipes, D. J., Green, B. A., Javier, S. J., Perrin, P. B., & Benetsch, E. G. (2014). The use of alcohol mixed with energy drinks and experiences of sexual victimization among male and female college students. *Addictive Behaviors*, *39*, 259–264. doi:10.1016/j.addbeh.2013.10.005
- Stockwell, T., McLeod, R., Stevens, M., Phillips, M., Webb, M., & Jelinek, G. (2002). Alcohol consumption, setting, gender and activity as predictors of injury: A population-based case-control study. *Journal of Studies on Alcohol*, *63*, 372–379. doi:10.15288/jsa.2002.63.372
- Woolsey, C. L., Jacobsen, B. H., Williams, R. D. Jr., Barry, A. E., Davidson, R. T., Evans, M. W. Jr., & Beck, N.C. (2015). A comparison of the combined-use of alcohol and energy drinks to alcohol-only on high-risk drinking and driving behaviors. *Substance Use and Misuse*, *50*, 1–7.
- World Health Organization. (2009). *Alcohol and injuries: Emergency department studies in an international perspective*. Retrieved from http://www.who.int/substance_abuse/msbalcainuries.pdf
- Ye, Y., Cherpitel, C. J., & Bond, J. (2010). Estimating risk of injury related to alcohol using case-control and usual frequency case-crossover methods: Discrepancies and potential bias [Abstract 913]. *Alcoholism: Clinical and Experimental Research*, *34*, Supplement 6, 239A. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1530-0277.2010.01210.x/epdf>