Legitimacy of concerns about caffeine and energy drink consumption

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Whether caffeine and energy drink consumption presents a critical emerging health problem is not currently known. Available evidence suggests that energy drink consumption represents a change in the ways in which individuals in the United States consume caffeine but that the amount of caffeine consumed daily has not appreciably increased. In the present review, the question of whether Americans are sleep deprived (a potential reason for using caffeine) is briefly explored. Reported rates of daily caffeine consumption (based on beverage formulation) and data obtained from both civilian and military populations in the United States are examined, the efficacy of ingredients other than caffeine in energy drinks is discussed, and the safety and side effects of caffeine are addressed, including whether evidence supports the contention that excessive caffeine/energy drink consumption induces risky behavior. The available evidence suggests that the main legitimate concern regarding caffeine and energy drink use is the potential negative impact on sleep but that, otherwise, there is no cause for concern regarding caffeine use in the general population.

Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

INTRODUCTION

Over the past several years, there has been a rising number of television and newspaper reports of a so-called epidemic of energy drink use in the United States; this has been supplemented by reports of energy drink-related illnesses and deaths and concerns about energy drink usage in vulnerable populations. The extent to which such reports are evidence-based and reflect legitimate concerns is unclear.

Perhaps the first question to ask is “Why are energy drinks consumed?” The answer seems straightforward: to increase energy. But what kind of energy is desired? Is it physical energy (e.g., strength, endurance, stamina)? Is it mental energy (e.g., alertness, mental acuity)? And what is the purpose (e.g., to work longer, harder, or better; to play longer and later into the night)? The answers to these questions may reveal both the nature of the problem that energy drink users wish to overcome and the extent to which the use of energy drinks (or the caffeine that many of them contain) represents an effective solution to the problem.

The present review is focused on caffeine’s alertness-enhancing effect as one reason for its use; investigations of other reasons (e.g., improving mood or cognition) that fall within the construct “mental energy” can be found elsewhere. Numerous articles pertaining to the impact of caffeine and energy drink use on physical performance have been published recently. The use of caffeine and caffeine-containing energy drinks to restore or maintain alertness may reflect attempts to get by with insufficient daily sleep and/or overcome the brain’s biological clock (e.g., to stay awake during nighttime hours when alertness is waning). These concerns are likely shared by a diverse population group in terms of age, occupation, and other demographics, but the present review is focused on the adult US population (18 years of age or older), including military personnel.

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Key words: alertness, caffeine, circadian rhythm, energy drinks, sleep
Daily reported sleep amounts

Do individuals in the United States suffer from a chronic sleep debt that they attempt to override by using caffeine-containing energy drinks to maintain alertness and mental performance? There appears to be inconsistency in the published literature regarding this issue. By some accounts (for example, the United States Bureau of Labor and Statistics’ 2012 American Time Use Survey), average daily sleep amounts, even on weekdays, appear to be within the 7–9 hours per 24 hours range that is currently recommended by the United States National Heart, Lung, and Blood Institute, which are also used in the recommendations of the United States Centers for Disease Control and Prevention. Results from the 2012 American Time Use Survey indicate that both men and women aged 15 years and older reported obtaining at least 8 hours of sleep per day (when averaged over all days of the week). However, results from a poll conducted by the National Sleep Foundation, when disaggregated along demographics such as type of employment, indicate substantial sleep deficits in certain populations – notably, shift workers who attempt to sleep during the day. Results from another survey disaggregated by age indicated that over 30% of adult respondents aged 45 years or older reported sleeping 6 or fewer hours per 24-hour period. In short, whether most Americans obtain sufficient sleep or not appears to vary depending on which survey results one considers.

Daily reported amounts of sleep in young adults (who are thought to be the main consumers of energy drinks) have received some attention. In a recent cross-sectional questionnaire study of college students (N = 561), respondents reported sleeping an average of 6.71 hours per night on weekdays and 8.30 hours per night on weekends (weekly average, 7.16 h). The Spring 2013 National College Health Assessment (N = 123,078 respondents) included several items pertaining to sleep quality and waking alertness (but not actual sleep amounts). Few respondents indicated that they obtained sufficient sleep to feel rested upon awakening on 6 or 7 nights per week (suggesting sleep debt). In contrast, the percentage that reported having to go to bed on 4 or more nights because they could not stay awake any longer also was relatively low (20.07% total). Only 6.61% of respondents reported that sleepiness was a problem during daytime activities. These results appear to corroborate those from Melton et al., suggesting that sleep debt among college students is mild (and possibly restricted to weekdays).

Daily reported caffeine use

What is the evidence, if any, that daily caffeine consumption is on the rise? Results from the 2001 through 2010 National Health and Nutrition Examination Surveys (NHANES) indicated that caffeine use among those who reported it remained relatively stable over that 10-year period for most age groups except for 35–39 years. In the latter age group, daily caffeine intake significantly decreased by 19 mg from 2001 to 2010. For the period 2007–2010, average daily reported caffeine intake was just under 150 mg for the 18–29 year age group, just over 200 mg for the 30–34 year group, just under 200 mg for the 35–39 year group, just under 250 mg for the 40–49 year group, just over 250 mg for the 50–59 year group, and just under 200 mg for those 60 years and older. Results by percentile indicated that average reported daily caffeine intake for those at the 90th percentile (i.e., highest reported caffeine intake) also was highest in those 40–49 years of age (just under 500 mg) and those 50–59 years of age (just over 500 mg). Average daily caffeine intake for those at the 90th percentile was just over 300 mg for 18–29 year olds (young adults). Evaluation of the sources of caffeine intake from the same NHANES data sets indicated that the amounts of caffeine consumed from different beverage types did not change significantly, except for a small but statistically significant increase in the amount of caffeine consumed in the form of energy drinks (1 mg per 2-year survey cycle or approximately 0 mg in 2001 to approximately 8 mg in 2010) and a statistically significant decrease in caffeine consumed in the form of sodas (approximately 55 mg in 2001 to just under 45 mg in 2010). Across all adult age groups, the main form in which caffeine was consumed was coffee.

Results from a 2010–2011 large-scale (N = 37,604) survey of caffeinated beverage intake (7-day diary) among US consumers appeared comparable to the NHANES data set, although direct comparisons are not possible since different age ranges were used. For individuals in the 18–24 year age group, daily reported caffeine consumption was 122.1 mg; for the 25–34 year group, daily reported caffeine consumption was 137.3 mg, which is approximately 60 mg lower than the daily intake for the 30–34 year group from the NHANES study. Similar to the NHANES results, the highest amount of reported daily caffeine consumption was found in the 50–64 year age group (225 mg/day). Consumption was also reported as a function of product type (see Fig. 1). Consistent with the NHANES results, for all age groups the main form in which caffeine was consumed was coffee. However, the amount of coffee relative to other beverage types was lower in younger adults than in older adults: for example, the 18–24 year age group consumed an average of 60.1 mg of coffee per day, 31.4 mg caffeinated soda drinks per day, 23.1 mg tea per day, and 6.2 mg energy drinks; in comparison, the 50–64 year age group consumed 158.6 mg coffee, 28.0 mg soda, 37.1 mg tea, and 1.3 mg energy drinks per day.
Caffeine and energy drink use in the United States military

Currently, no yearly survey of caffeine use is conducted among the active-duty US military population. However, some descriptive statistics are available from several different sources, one of which consists of in-theater (i.e., in deployed troops) surveys conducted by the United States Mental Health Advisory Teams. Such surveys are conducted at the request of a given military branch’s senior operational leadership and executed through the Office of The Surgeon General of the Army with support from military branch Command Surgeon Offices. In the most recent survey, US Soldiers and Marines deployed in support of Operation Enduring Freedom (Afghanistan theatre of operations) completed a detailed survey that included an item regarding energy drink use. Participants were asked, “How many energy drinks (e.g., Red Bull, Monster, 5-Hour Energy) do you use per day?” Possible responses ranged from 0 to “5 or more” in one-integer increments. Results are shown in Figure 2 (data from 14). The relationship between the percentage of individuals reporting daily use and the reported number of energy drinks consumed per day followed a saturating exponential function: the percentage reporting consumption of a given number of energy drinks decreased as the number of energy drinks increased. This pattern was evident among junior enlisted (approximate age range, 18–24 years), senior enlisted (approximate age range, 25–39 years), and officer/warrant officer (approximate age range, 28–46 years) personnel. Interestingly, 55.2% of all respondents indicated that they used no energy drinks. It is not clear whether this response means that these individuals used no caffeine at all, since the survey did not contain additional questions about consumption of other forms of caffeine (e.g., coffee, sodas).

Jacobsen et al.15 described energy supplement use in military volunteers participating in the 2007–2008 Millennium Cohort Study. The Millennium Cohort Study is a longitudinal assessment of various health factors in military members that was initiated in 2001 and is administered every 3–4 years. In the 2007 assessment, volunteers were asked whether they had taken energy supplements such as energy drinks, pills, or energy-enhancing herbs in the last 12 months. Odds ratios for reporting energy supplement use were higher in the following groups: 1) men and women who reported less than the recommended 7–8 h of sleep per night; 2) men and women who also reported using body-building supplements or weight-loss supplements; and 3) men and women reporting trouble sleeping. Overall, the odds ratios for reports of energy drink usage were slightly higher among those who reported deployment experience, regardless of gender.

Lieberman et al.16 conducted a detailed caffeine use survey of the active duty military population in 2007. Their survey included a question listing 31 caffeine-containing items (e.g., beverages, foods, dietary supplements) and respondents reported the amount and frequency of consumption. Respondents could also enter caffeine-containing products that were not listed on the survey. Total average daily caffeine consumption (summed across all caffeine formulations) was 285 mg, ingested mainly in the form of coffee (127 mg/day) and energy drinks (79 mg/day). Total caffeine consumption differed as a function of gender (males, 365 mg; females, 216 mg), race (other, 334 mg; white non-Hispanic, 318 mg; Hispanic, 280 mg; black non-Hispanic, 139 mg) and tobacco use (current use, 421 mg; former use, 327 mg; never used, 190 mg). The amount of caffeine...
ingested in various formulations differed by age group; coffee consumption was higher in respondents aged 40 years or older (312 mg) compared to other age groups, and the amount of caffeine consumed as “other soda” and as “energy drink” was higher in respondents aged 18–24 years (42 mg and 120 mg, respectively) and 25–29 years (36 mg and 125 mg, respectively) compared to older respondents. The latter results correspond to those reported above for a civilian population and suggest that younger adults are more likely to consume their daily caffeine via formulations other than coffee.

In sum, results from surveys of the US population overall, as well as subgroups comprised mostly of young adults (e.g., active duty military), indicate that the main consumers of caffeine are not young adults but rather are older adults over 40 years of age.

Other energy drink ingredients

The list of ingredients in energy drinks that are advertised to confer some kind of benefit is daunting (even to scientists and physicians). The most frequently listed are caffeine, taurine, sugar, B-vitamins, and guarana (see table 1 in McLellan and Lieberman23). Which of these components, if any, possesses demonstrated biological activity that could be construed as conferring “energy”? Caffeine. Caffeine leads the inventory of energy drink ingredients – and with good reason: results from numerous studies show that caffeine at dosages of 100 mg or more improves neurobehavioral performance and alertness, most notably under conditions of insufficient sleep and at or near the circadian alertness trough.18 Although caffeine exerts several biological actions, its neurobehavioral effects are mainly mediated via antagonism of brain adenosine receptors (specifically, the A1 and A2A receptor subtypes, with variants in the latter also playing a role in caffeine sensitivity).19 As adenosine itself modulates various neurotransmitter systems, antagonism of adenosine receptors via caffeine administration potentially affects neurophysiological systems that are involved in neurobehavioral performance. Caffeine’s abuse liability is relatively low compared to other psychostimulants,20 most likely because doses above approximately 300 mg have been reported to cause side effects including nausea, anxiety, jitteriness, heart palpitations, etc.21,22

Taurine. Taurine is an amino acid found naturally in dairy, meat, and seafood. As reviewed by Mahoney and Lieberman,23 limited results from animal model studies suggest that taurine acts as a GABA receptor antagonist and, thus, might be predicted to enhance learning and memory, decrease anxiety, and improve mood, suggesting a rationale for its inclusion in energy drinks. However, evidence that taurine exerts any of these neurobehavioral effects is notable for its absence. Results from several well-controlled experiments (summarized by Mahoney and Lieberman23) failed to demonstrate that taurine possesses utility as an energy-enhancing compound.

B vitamins. Various combinations of the B vitamins (B1 thiamine, B2 riboflavin, B3 niacin, B5 pantothenic acid, B6 pyridoxine, B7 biotin, B9 folic acid, and B12 cobalamin) are among the next most frequent constituents of energy drinks. In their review of energy drink components, McLellan and Lieberman17 determined the following: “There is no experimental evidence showing that the addition of multivitamins to a caffeinated energy drink will cause greater improvements in physical and cognitive performance than can be attributed to the effects of caffeine alone” (p. 736). A broad-based PubMed search (“vitamin” AND [“cognitive performance”] OR [“neurobehavioral performance”] OR [“alertness”] OR [“mood”]) failed to reveal well-controlled, peer-reviewed reports of studies in which an objectively measured benefit on neurobehavioral performance was derived from administration of B vitamins in an otherwise healthy, adult population.

In addition to the above constituents, energy drinks contain various kinds of sugars. These contribute to the overall caloric load but have no demonstrated neurobehavioral-enhancing effects in healthy adults.

Safety of caffeine dose

Caffeine is arguably one of the most studied psychoactive compounds, with literally thousands of articles published to date regarding its side effect profile and safety. It is beyond the scope of this article to comprehensively review that literature; therefore, what follows is a brief description of caffeine guidelines followed by a brief overview of several publications in which caffeine’s side effects are described.

The U.S. Food and Drug Administration (FDA) draws a distinction between caffeine occurring naturally in coffee and tea and caffeine as an additive to cola-type beverages. In the former, caffeine is classified as GRAS (generally recognized as safe) whereas for the latter, the FDA indicated the following: “While no evidence in the available information on caffeine demonstrates a hazard to the public when it is used in cola type beverages at levels that are now current and in the manner now practiced, uncertainties exist requiring that additional studies be conducted.”24 (The exact nature of the “uncertainties” was not specified in the FDA report.) The FDA lists 400 mg per day as the “amount not generally associated with dangerous, negative effects.”25 This amount is consistent with guidance from the World
Health Organization, which defines acute or chronic “overuse” as a daily intake of caffeine of 500 mg or more; adverse consequences are referred to as “caffeineism.” It is not clear from the World Health Organization definition of “caffeinism” whether ingestion of caffeine at levels at or above 500 mg that does not cause adverse effects (i.e., caffeineism) is considered safe. The International Classification of Diseases manual further lists caffeine as a potential cause of mental and behavioral disorders, but specific caffeine amounts are not indicated, and it is not clear whether “caffeinism” and caffeine as a potential cause of mental or behavioral disorders are considered synonymous. Several caffeine-related disorders are listed in the most recent Diagnostic and Statistical Manual of Mental Disorders (DSM-5), to include caffeine intoxication. The dose of caffeine causing intoxication is specified only as “typically a high dose well in excess of 250 mg.” Similarly, fatal doses of caffeine are specified only as “extremely high.” Caffeine withdrawal is listed as a separate disorder, with the dose unspecified other than “cafeine withdrawal symptoms may occur after abrupt cessation of relatively low chronic daily doses of caffeine (i.e., 100 mg).”

A distinction (perhaps artificial) can be drawn between caffeine’s effects on the central nervous system (e.g., mood alterations to include increased anxiety – briefly described below) and caffeine’s effects on the peripheral (sympathetic) nervous system (blood pressure, heart rate, and body temperature). Of these, caffeine’s impact on cardiovascular function could, perhaps, be considered the most likely to adversely affect safety (although it is recognized that caffeine’s other effects may negatively impact health in certain subpopulations; for example its impact on blood glucose in diabetics). In a recently published meta-analysis, it was concluded that caffeine at or above 400 mg does not increase risk of atrial fibrillation. In another meta-analysis, caffeine at or below 300 mg was determined to be safe even in those with high blood pressure. These results corroborate published guidelines described above regarding the generally good safety profile of caffeine at doses below approximately 400 mg per day. Cases of caffeine overdose have been reported in the open scientific literature, but such cases involved ingestion of caffeine doses far exceeding the 400 mg cutoff (and generally exceeding 5 g). Although some overdoses resulted in death, individuals have survived overdoses as high as 50 g.

**Subjective side effects of caffeine**

Whether caffeine’s subjective side effects pose a safety hazard is perhaps debatable. Nonetheless, side effects are widely reported, may impact objective performance, and also serve as the basis for DSM-V diagnoses. Subjective side effects evaluated in several select studies (in which more than one dose level of caffeine was evaluated, thus allowing for determination of dose-response effects) are described below to illustrate those side effects commonly resulting from caffeine use.

**Side effects of caffeine in non–sleep-deprived volunteers**

Side effects of caffeine have been reported in studies of non–sleep-deprived volunteers. In one such study, a dose-dependent increase in reports of jitteriness/nervousness/shakiness (caffeine doses = 0, 100, 200, 400, and 600 mg) in non–sleep-deprived volunteers was found, and even the lowest caffeine dose (100 mg) was statistically different from placebo. Dose-dependent effects also were found for ratings of “dislike effects,” but the difference from placebo was significant only for the 400 and 600 mg doses. In another study of habitual smokers, effects of repeatedly administering caffeine in an ascending dose schedule (i.e., caffeine 200, 400, or 800 mg) were examined. In that study, one volunteer experienced shakiness and an upset stomach after 200 mg of caffeine and was therefore not tested at higher caffeine doses. Caffeine was associated with a dose-dependent increase in ratings of tension-anxiety that was statistically significant from placebo for all three doses. In addition, a scale associated with dysphoric and somatic symptoms was dose-dependently increased, but only the 800 mg dose was statistically significant from placebo. The 800 mg dose also significantly increased ratings on a scale measuring general drug-induced euphoria, compared to placebo. Because the volunteers were allowed to smoke following caffeine consumption, it is possible that the symptoms reported at high caffeine doses may have been due to nicotine. No other adverse effects of caffeine at 800 mg were reported for any of the 5 study volunteers who received all doses. Results from these studies indicate that in non–sleep-deprived volunteers, doses of caffeine that exceed the recommended daily intake are generally well tolerated.

**Side effects of caffeine in sleep-deprived volunteers**

Because caffeine often is used to overcome sleepiness associated with insufficient sleep, its impact on performance and alertness in sleep-deprived individuals has received much attention. Caffeine has been administered in sleep-deprived volunteers in single bolus doses of up to 600 mg. In one such study, frequency of reports of anxious-ness, irritability, jitteriness/nervousness, sleepiness, talkativeness, pounding heart, headache, sweetiness, and upset stomach following caffeine at doses of 150, 300, or 600 mg/70 kg body weight, administered after 48 h of
wakefulness; although the authors reported that these effects showed a dose-dependent function, the minimal caffeine dose at which these effects were found was not reported.39 In another study, 600 mg of caffeine administered following 41 hours of sleep deprivation resulted in reports of pounding heart and nausea, and 2 of the 10 volunteers receiving the 600 mg dose vomited approximately 2 h after caffeine administration.23 Caffeine at doses of 1.5–3.0 mg/kg (approximately 100–200 mg for an average adult male) was associated with increased systolic and diastolic blood pressure, although neither was raised by more than 6 mm/Hg, and all values were within normal ranges (systolic below 140; diastolic below 90).

As noted above, in a portion of the numerous human use caffeine studies published to date, volunteers who were totally or partially sleep-deprived and ingested a bolus (single) dose of up to 600 milligrams experienced no serious adverse consequences and few nonserious side effects. It is possible that this generally low rate of caffeine-related adverse effects is a function of self-selection, with those individuals who have experienced negative reactions to caffeine choosing to not volunteer for participation in studies involving caffeine administration. However, although results from the literature available to date indicate that, at doses up to 600 mg, caffeine causes few untoward effects, the generally agreed upon safe upper limit of daily caffeine dosing is 400 mg, likely ingested as several smaller doses (e.g., 50–100 mg) across the day.

Association of caffeine with behavioral and other health problems

To what extent is caffeine use, including that in energy drinks, linked (most notably in a causal fashion) to behavioral or other health problems? The answer is that there is presently no evidence causally linking caffeine or energy drink use to any behavioral or other health problem.

However, there is a growing amount of literature linking insufficient sleep with behavioral and other health problems. Over the past two decades, evidence that chronic sleep disturbance is associated with mood disorders,40 impaired immune function,41 age-related cognitive decline,42 metabolic syndrome/obesity/diabetes,43 heart disease,44 and even cancer45 has steadily accrued. Thus, insufficient sleep is a more plausible cause of behavioral and other health problems that, on the surface, appear to be directly linked to energy drink/caffeine usage. For example, Toblin et al.14 correlated the reported number of energy drinks consumed per day with frequencies of reporting that the following disrupted sleep on more than 50% of the past 30 nights (selection of one cause was not mutually exclusive of others): 1) stress related to combat, 2) stress related to personal life and problems, 3) poor sleep environment (too noisy, bright, hot, cold, etc.), 4) high operational tempo, 5) nighttime duties, 6) off-duty leisure activities (video games, movies, etc.), 7) illness, and 8) other. Of these eight causes of disrupted sleep, only three (stress related to combat, stress related to personal life, and illness) were reported as occurring on more than 50% of the past 30 nights by individuals who also reported consuming 3 or more energy drinks per day. Although it could be construed that the relationship was causal in nature (i.e., that caffeine use disrupted sleep), an equally likely explanation is that insufficient sleep increased sleepiness, and that sleepiness was the driver of both the caffeine use and reports of stress. It is possible, depending on timing of caffeine use (discussed below), that, as suggested by Toblin et al.,14 caffeine directly impaired sleep. However, the timing of caffeine consumption was not addressed in the MHAT survey; in fact, such information is generally not collected in caffeine use surveys although it is critical for determining the extent to which caffeine use could be driving sleep disruption (discussed further below).

It also has been reported that adolescents and young adults who consume excessive amounts of energy drinks also engage in other risky behaviors.46 Although it has been hypothesized that excessive caffeine use causes risky behavior, the most parsimonious explanation for this relationship is that excessive energy drink use is simply another manifestation of risk-taking expressed by individuals who are already predisposed to engage in risky behaviors. Results from a January 201347 report from the Drug Abuse Warning Network lend some support for the latter hypothesis. That is, although the overall number of emergency department visits related to energy drink use increased from 10,068 visits in 2007 to 20,783 visits in 2011, almost half (8,652) were associated with another psychoactive compound. Because it does not appear that urine drug tests were conducted, it may be that the number of energy drink–related visits associated with other psychoactive compounds may be larger than that reported. Consistent with other results showing that adolescent males engage in more risk-taking behavior than do older males and females of any age (which appears to be at least partly explained by gender differences in brain development48), results also showed that males and individuals aged 18–25 years comprised the bulk of energy drink-related emergency department visits.

Caffeine’s impact on tasks that are purported to measure aspects of risk-taking has received some attention. In one recently published study, volunteers were administered alcohol only (0.5 g/kg), an energy drink only (3.57 mL/kg; caffeine content not reported although the authors indicated that Red Bull 250 mL/70 kg was used), an alcohol-containing energy drink, or placebo.49 The researchers performed the computerized Balloon Analogue Risk Task (“BART™) at 30 and 125 min post-
administration. The BART involves pumping a balloon to earn money. For a given trial, each pump earns money but it also fills the balloon further. Volunteers choose when to stop inflating the balloon and "cash in" to start the next trial. However, volunteers do not know when the balloon will explode, so each press of the button to inflate the balloon is associated with risk. Compared to placebo, energy drink consumption marginally (p = 0.05) increased the mean adjusted average number of pumps (40.3 for placebo versus 44.5 for energy drink). No other BART outcome metrics differed between the placebo and energy drink groups.

The BART has also been utilized in two separate investigations to evaluate the impact of caffeine on risk-taking during sleep loss. In the first study, volunteers (mean age, 25.4 years; range, 20–35 years) remained awake for 75 h and were administered repeated doses of caffeine (200 mg) or placebo across nighttime hours (total caffeine dose per night, 800 mg; total cumulative dose, 2,400 mg). Caffeine did not increase risk-taking as measured by the total number of exploded balloons or a cost-benefit ratio metric (which quantifies risk taken relative to amount earned). In the second study, volunteers (mean age, 23.5 years; range, 18–36 years) received 600 mg of caffeine administered after 44 h of sleep loss and no effect on risk-taking was found, as measured by either the BART or the Iowa Gambling Task (IGT). The volunteers included those who were older than a typical college student; nonetheless, no evidence that caffeine induced risky behavior was found.

To summarize: there is no evidence that the caffeine (or any other ingredient) contained in energy drinks directly causes behavioral or other health problems. In the adolescent/young adult population, the most likely explanation for co-occurrence of excessive energy drink/caffeine use and risky behaviors is the well-known age- and gender-related neurophysiological vulnerability to engage in risky behaviors.

**Future trends in caffeine use**

A distinction should be drawn between evidence that caffeine use is on the rise and speculations or predictions that caffeine use may be currently on the rise and/or continue to increase over the next few years. As shown in the sections above, there is presently no evidence that caffeine use is on the rise. Rather, the evidence suggests that the forms in which Americans consume their daily caffeine has changed.

However, it seems reasonable to speculate that 21st century lifestyle changes (e.g., increased availability of electronic social media, affordability of communication devices such as cell phones) and work habits (longer work week in the United States) will drive Americans to increasingly forego sleep for social and work-related activities. When work or social activities delay sleep times, the resulting neurobehavioral deficits have been referred to as "social jetlag." It is, therefore, not surprising that individuals would choose to use energy drinks to boost feelings of alertness or physical energy. The available evidence does not indicate there is any inherent danger associated with using energy drinks within daily limits (below 400 mg/day) to support mental or physical energy, so are there any reasonable causes for concern?

**Caffeine and sleep impairment**

Most of us are familiar with the morning routine of waking up with a cup (or several cups) of coffee. This practice of consuming coffee upon waking is widespread for good reason: it represents an effective use of caffeine to overcome reduced alertness at our usual circadian trough (which coincides with habitual awakening time) and post-awakening sleepiness (i.e., sleep inertia). Because caffeine is so effective at blocking sleepiness, a reasonable concern associated with its use would be its potentially disruptive impact on subsequent sleep. Indeed, results indicate that caffeine consumption reduces total sleep time.

**CONCLUSION**

The only ingredient in energy drinks that has well-documented, psychoactive (alertness and performance-enhancing) effects is caffeine. At daily doses below 400 mg, caffeine is a safe, temporary means of improving mental and physical energy. There is no evidence that caffeine itself causes risky behavior. Caffeine can negatively impact sleep, however, and this represents a legitimate concern regarding its use in any age group and in any form. Therefore, educational efforts that focus on the deleterious effects that caffeine and caffeine-containing energy drinks exert on sleep, rather than on other unsubstantiated concerns, would be the most beneficial.

**Acknowledgments**

**Funding.** The author acknowledges the United States Army Medical Research and Materiel Command Military Operational Medicine Research Program Directors for financial and scientific support of the ideas presented in this article.

**Declaration of interest.** The author of this paper maintains no financial or personal relationships that bias the information presented in this manuscript. No individuals other than the author participated in writing or providing other assistance during preparation of this manuscript.
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