Effect of energy drink and caffeinated beverage consumption on sleep, mood, and performance in children and adolescents

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The increasing availability of highly caffeinated beverages, including energy drinks, in the United States has resulted in a rise in consumption by children and adolescents. In addition, there is mounting evidence that these products are often consumed by youth for their perceived fatigue-mitigating and mood- or performance-enhancing effects. Although such perceptions by children and adolescents about the potential consequences of caffeine consumption are highly likely to influence decision making regarding the use of such products, there is still a relative paucity of studies that focus on the effect of caffeinated beverages on sleep, mood, and performance in the pediatric population. This review summarizes the following aspects of this topic, as derived from the information currently available: 1) the perception, among youth, of caffeine's risks and benefits and the sources of information about caffeine, particularly with regard to sleep, mood, and performance; 2) the bidirectional effect of caffeine on sleep in children and adolescents and the association of caffeine with other sleep-related practices, and 3) the evidence that supports caffeine as a performance and mood enhancer as well as a countermeasure to sleepiness in the pediatric population. Finally, gaps in knowledge are identified, and a direction for future research is outlined.

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INTRODUCTION

As the availability of highly caffeinated products such as energy drinks has increased, exposure to these beverages in the pediatric population has also risen. Moreover, there is an increasing trend for these products to be consumed by older children and adolescents, both for their perceived role as a countermeasure to sleepiness and fatigue and for their alleged positive effect on mood and performance. However, the scientific evidence supporting the ability of these beverages, including energy drinks, to enhance alertness, mood, and performance, specifically in the pediatric population, is still quite limited. In addition, the sources of information available to youth about the positive effects of caffeine use are often linked to marketing campaigns for specific beverages (e.g., “Red Bull gives you wings”) and thus do not include mention of potential risks related to early and/or excessive consumption.

While pediatric healthcare providers can be an important source of information about caffeine consumption, limited attention has been given to assisting them in educating and advising pediatric patients and caregivers about the potential short- and long-term risks and benefits in general and the effect on sleep and performance in particular. For example, a 2004 publication from the American Academy of Pediatrics about the health risks of soda focused solely on the caloric content of soft drinks and the relationship between obesity and soft drink consumption without mentioning the risk of exposure to caffeine. Another recent American Academy of Pediatrics publication addressed the risks of energy drink consumption in children specifically but included

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very limited mention of associated sleep problems and nothing about the potential use of energy drinks as perceived antidotes to sleepiness or as mood or performance enhancers, especially in the adolescent population.\(^2\)

In order to address these knowledge gaps, this review focuses on the evidence both in support of and refuting the perception that high levels of caffeine consumption mitigate the effect of sleep loss and sleepiness and improve performance and mood in children and adolescents. It should be noted that studies pertaining specifically to energy drink consumption in children and adolescents are cited when available, but currently there are far fewer data on the effect of energy drinks in this population than on the effects of other caffeinated beverages (e.g., soda, coffee). Thus, some degree of extrapolation from the broader literature on caffeine product use in children is necessary, with the understanding that the clearly significant difference in the typical amount of caffeine in a serving size of soda (55–69 mg per 12-oz can) or coffee (100–160 mg per 12-oz drink) compared with that in energy drinks (160–357 mg per 16-oz can; 208 mg per 1.9-oz “shot” serving) is a limitation of this approach.\(^3\)

Specific topics addressed in this review include the following: 1) common sources of information about caffeine, particularly with regard to sleep, mood, and performance and how the potential benefits and risks of caffeine consumption are perceived by children and adolescents; 2) a summary of the bidirectional effect of caffeine on sleep and of the association between caffeine use and other sleep-health-related practices in the pediatric population; and 3) the effectiveness of caffeine as a means of performance and mood enhancement and as a countermeasure to sleepiness in children. Finally, knowledge gaps are identified and potential future research directions outlined.

**CAFFEINE CONSUMPTION IN YOUTH: KNOWLEDGE AND ATTITUDES**

Recent data suggest that energy drink consumption is on the rise, more than doubling in children aged 2 to 11 years, from 3% in 2000 to 7% in 2008.\(^4\) In the same study, the prevalence of sports/energy drink consumption in adolescents has tripled (from 4% to 12%). It should be noted, however, that most of the previous studies examining caffeine consumption by children and adolescents were largely focused on coffee drinks and carbonated caffeinated beverages. For example, while the 2004 National Sleep Foundation Sleep in America poll found that 18% of preschoolers, 33% of older school-aged children, and 28% of younger school-aged children consumed >1 serving of caffeinated beverages per day, energy drink consumption was not reported separately.\(^5\) The results of the 2006 National Sleep Foundation poll in adolescents found that 35% of high school students consumed at least 2 servings of caffeinated beverages per day (i.e., caffeinated soda, coffee, etc.), with a higher percentage observed among minority adolescents and those from low-income families.\(^6\) However, that poll also did not examine energy drink consumption independently.

There is mounting evidence that some of the most important factors influencing the use of highly caffeinated beverages in older children and adolescents include the perceived positive effects on mood, performance, and alertness or energy level. While only a limited number of studies have examined the expectancies of children and adolescents regarding the use of caffeinated beverages, some general conclusions may be drawn from the existing literature. In one of the earliest studies to examine this issue, the expectation of an “energy boost” from energy drinks in 11- to 18-year-olds in Australia was commonly reported.\(^7\) This study also found that adolescents report using energy drinks for the “buzz” and that these beverages make them “feel more energetic.” Another study found that adolescent high consumers of caffeine (>50 mg/day) reported using caffeine to stay awake more than low consumers (<10 mg/day) and that boys were more likely than girls to report getting a “rush,” more energy, or improved athletic performance from caffeine.\(^8\) Caffeine use may also serve as an affect modulator, particularly when it comes to adolescents with excessive daytime sleepiness or insufficient sleep.\(^9,10\) For example, an examination of caffeine consumption in depressed adolescents found an increased use of caffeinated products, suggesting an expectancy, at least in this population, of improved mood regulation, alleviation of depression, and reduction of anxiety.\(^10\)

In one of the few studies to examine expectancies for caffeine use specifically in high school students, consumption of caffeine beverages overall was high (68% reported use in the past 48 h and, of those, 86% had consumed caffeine in the past 24 h).\(^11\) Although the rate of recent energy drink consumption was relatively low (6.1%), use was higher in males than in females. Students reported both positive and negative expectancies, including withdrawal/dependence, sleep disturbance, increased energy, and appetite suppression (especially in females), but the perceived intensity of overall effect of caffeine was low. When the group was divided into high-soda-use, mixed-use (coffee/soda, energy drinks, caffeine pills), and low-caffeine-use clusters, however, some interesting differences emerged. Mixed users reported more daytime sleepiness, tended to consume caffeine earlier in the day, reported more dependence on caffeine to “get through the day,” were more likely to use energy drinks, and had overall higher expectancies for a positive effect on energy/performance/mood and for appetite suppression. This relationship between perception of positive effects and
increased use (and vice versa) was also found in a recent study of 6th to 8th graders (n = 916).12

Furthermore, these expectations about the positive effect of high levels of caffeine consumption among older children and adolescents are often not counterbalanced by adequate or accurate knowledge of the potential associated health risks. In the study of middle school students, only 6.4% of high consumers versus 60.4% of low consumers of energy drinks endorsed the statement "energy drinks are bad for your health."12 In a study of energy drink consumption among female secondary students in Saudi Arabia, of whom 52% self-reported use, almost 70% did not know what active ingredients were contained in the beverages they consumed.13 In particular, compared with adults, adolescents as a group may be overall less concerned with the safety of these products (i.e., they assume that any products on the market by definition are not harmful), despite having some awareness of the potential health effects.14

While not the primary focus of this review, other factors can influence caffeine consumption and should be acknowledged. These include external factors such as social pressures. In the Saudi Arabian study cited above, "vitality" and "alertness" were cited as reasons for use, yet current energy drink use was also positively associated with consumption by a family member or close friend.13 A qualitative study that compared adolescents (16–21 y) with young adults (22–35 y) examined factors driving the intent to purchase energy drinks.15 While energy-seeking (e.g., getting a "kick/hit") was associated with the use of beverages with a higher caffeine content, most of the adolescent participants perceived that energy drink consumption primarily served a social function (as compared with having a physiologic effect).

Finally, it is important to note that a number of characteristics of energy drinks, including their packaging, marketing, and availability, may contribute to perceptions by youth about the use and health effects of these drinks. Energy drinks are often sold both as single-serving, non-resealable “drinks” with a high caffeine content and large serving size (160–357 mg per 16 oz can) and as "shots," which typically contain much higher levels of caffeine (115–208 mg per 1.9 oz serving), and whose small portion size encourages rapid consumption.3 While the American Beverage Association has suggested voluntarily restricting the marketing and sales of energy drinks to children under 12 years of age, youth-targeted advertising of these products through social media vehicles, youth-oriented events, websites promoting physical activity and performance enhancement, especially with regard to sports, and sponsorship of extreme sports events and music concerts clearly appeals to pre- and early adolescents as well as to young adults. Self-report studies in young adolescents have suggested that the popularity of these beverages is attributed to advertising by a substantial percentage of the respondents.15 Compared with young adults, adolescents tend to have higher levels of consumption overall, are more likely to respond to advertisements emphasizing packaging and image, have less awareness of age-specific targeted marketing, and exhibit more brand loyalty.15 Furthermore, advertising of these products often targets consumers (e.g., adolescents) who get insufficient sleep and are seeking pharmacologic means to reduce excessive daytime sleepiness.8 Finally, these beverages are widely available in convenience stores (retail sales of the "5 Hour ENERGY" product were over 1 billion dollars in 2011), with no restrictions in many countries, including the United States, on sales to children or adolescents.16

CAFFEINE AND SLEEP

In contrast to the established body of literature on the sleep-disrupting effects of caffeine in adults,17–19 the effect of caffeine on sleep has not been well studied in the pediatric population. For example, studies in adults have found that caffeine reduces the percentage of time spent in slow-wave or deep sleep in a dose-related manner and alters the temporal organization of rapid eye movement (REM)/non-REM sleep.18,20 This is particularly important because both slow-wave sleep and REM sleep play critical roles in learning and memory consolidation. There are, however, few data on the effect of caffeine on sleep architecture in the pediatric population.

In studies that have examined the relationship between caffeine consumption and behavioral sleep disruption in children and adolescents, caffeine intake has been consistently associated with shorter sleep duration, increased sleep onset latency, and increased wake time after sleep onset.20–26 In a secondary retrospective analysis of data from a 2004 National Sleep Foundation poll, caffeine use was associated with a reduction in total sleep time of 15 minutes in school-aged children.27 Another study found that preschoolers (aged 3–6 y) who consumed caffeine were found to have a reduction of 42 minutes in total sleep time.28 It should be noted, however, that not all studies have found a relationship between caffeine and sleep deficiency, including one study of older adolescents (ages 14–21 y)29 and another of students entering primary school.30

The extent of sleep disruption may be associated with both lack of habituation (e.g., parent-reported increased sleeping difficulty after caffeine ingestion in children who are low consumers)31 and increased levels of consumption.32 For example, analysis of a 1998 National Institute of Child Health and Human Development survey found that high caffeine intake in more than 15,000 6th–10th graders was associated with a 2-fold
increase in difficulty sleeping and morning fatigue.\textsuperscript{21} In one of the few studies to examine caffeine intake and sleep in school-aged children prospectively (2-wk diary of sleep and caffeine use), higher caffeine intake was associated with decreased sleep duration and increased wake after sleep onset.\textsuperscript{22} Adolescents with high caffeine intake also report increased difficulty sleeping and more disturbed sleep.\textsuperscript{21,23} Caffeine use has also been associated with parasomnias. For example, a study of 144 early adolescents (ages 11–14 y) found that the amount of caffeine consumed was significantly correlated with sleepwalking, bruxism, and head banging.\textsuperscript{23}

On the other hand, gradual cessation of caffeine consumption may result in improved sleep. For example, in one study involving Guatemalan toddlers (aged 12–24 mo) who consumed coffee daily, the randomized discontinuation of caffeine increased sleep by an average of 30 minutes per night.\textsuperscript{24} This phenomenon may also provide an alternative explanation for improved psychomotor performance observed following caffeine administration in experimental settings. If sleep quality improves with discontinuation of caffeine during the washout period prior to administration of caffeine, then improved performance on neurocognitive tasks after a dose of caffeine may actually reflect better sleep rather than the direct effects of caffeine per se.

Finally, and not surprisingly, increased caffeine use frequently coexists with other behaviors that negatively affect sleep, such as adolescents’ late-night, multifaceted technology use. For example, in the 2006 National Sleep Foundation poll, those adolescents who consumed 2 or more servings per day were more likely to have other unhealthy sleep habits (e.g., later bedtimes, more electronic devices in the bedroom, greater weekday/weekend discrepancy) as well as sleep problems such as increased sleep onset latency, difficulty staying asleep, and shorter sleep duration.\textsuperscript{25} A recent study found that high-school-aged adolescents who reported the highest levels of multitasking with media-related electronic products also consumed the most caffeine.\textsuperscript{27} Caffeine consumption is also linked to nicotine use in adolescents,\textsuperscript{25} which in turn may further disrupt sleep and perpetuate the cycle of sleep fragmentation, i.e., daytime sleepiness and stimulant use.\textsuperscript{26}

**CAFFEINE AND PERFORMANCE**

While caffeine use, especially in adolescents, appears to be increasingly targeted towards both improving performance and mood and mitigating the effects of chronic insufficient sleep, the evidence that consumption of highly caffeinated beverages actually enhances performance or reverses sleepiness in the pediatric population is slim. With regard to performance enhancement, lab studies in adults often show improvement in attention and psychomotor skills (e.g., reaction time) but more mixed effects on short- and long-term memory and complex cognitive functions.\textsuperscript{27} Studies examining the effect of energy drinks on performance specifically in young adults have demonstrated decreased reaction time, increased subjective alertness, improvements in memory and concentration, and increased aerobic and anaerobic endurance,\textsuperscript{38} although not all studies have found positive effects on psychomotor function.\textsuperscript{29}

Nevertheless, while these temporary alertness-enhancing effects of caffeine are well documented in adults, there is much less information available about the complex relationship between caffeine, sleep, and alertness in children, and there are virtually no data on performance enhancement due to energy drink consumption specifically in children. In healthy children, studies of the effects of caffeine (in doses ranging from 2.5 mg to 100 mg) on performance in experimental settings have yielded mixed results. While 3 studies have shown improvement in vigilance or reaction time, attention, and manual dexterity,\textsuperscript{40–42} there is little evidence of enhanced cognitive effects. In a fourth study, the dose effect appears to be dependent on the dose of caffeine used (120 mg versus 146 mg) and the extent and duration of previous caffeine exposure.\textsuperscript{43} With regard to caffeine exposure, an important question is whether caffeine improves performance relative to baseline or just restores it following impairments secondary to sleepiness. For example, in experimental studies in adults, those who are frequent consumers of caffeine may experience withdrawal symptoms that include rebound sleepiness following acute discontinuation. The resumption of caffeine consumption in these individuals may simply serve to “reverse” these withdrawal effects.\textsuperscript{44–46} Indeed, high basal rates of sleepiness have been reported in study participants who habitually consume “normal” amounts of caffeine.\textsuperscript{20} Caffeine withdrawal-related deterioration in performance (e.g., lower response time) in children has also been reported and may persist for up to 1 week.\textsuperscript{48} More recently, a double-blind, placebo-controlled study comparing 35 caffeine-consuming 9- to 11-year-olds with low or non-consumers showed that, after overnight abstinence, higher consumers had poorer performance on cognitive tasks. Moreover, accuracy improved more in child consumers following consumption of caffeine versus placebo, supporting the applicability of the “withdrawal reversal” hypothesis of caffeine effects in children as well as in adults.\textsuperscript{47}

Several studies have indicated that caffeine use is associated with daytime sleepiness in the pediatric population.\textsuperscript{48} For example, high school students who report a moderate-to-high versus very-low intake of caffeine were nearly 2 times more likely to report morning sleepiness as
well as difficulty sleeping.\textsuperscript{21} Another study of 100 adolescents (ages 12–18 y) found that one-third of students reported falling asleep in class; caffeine consumption was 76\% higher in those who reported sleeping in school.\textsuperscript{25} Caffeine consumption has not only been positively correlated with daytime sleepiness but, in turn, negatively correlated with academic achievement. For example, a study of over 7,000 adolescents found that a significant proportion of the variance in academic achievement was attributable to caffeine use and further postulated that daytime sleepiness might be an important mediator of the negative effect of not only caffeine use but also of alcohol use and cigarette smoking on academic success.\textsuperscript{49} Unfortunately, adolescents, who as a group are overwhelmingly chronically sleep deprived, may consume excessive caffeine in an attempt to mitigate the effects of sleep loss, to reduce daytime sleepiness, and to restore and/or enhance academic performance. This practice, which has – at best – limited empirical support in terms of effectiveness, may further compromise the quality and quantity of sleep and lead to increased use of and dependence on caffeine.

### CAFFEINE AND MOOD

Studies in adults about the effect of caffeine on mood have yielded mixed results. Some have found that both caffeine consumption and the expectation of having consumed caffeine have some mood-enhancing effects.\textsuperscript{50} A number of authors have postulated that these effects are largely due to the reversal of caffeine withdrawal symptoms in heavy consumers, but others suggest there may be some direct effect on mood,\textsuperscript{51} even in nondependent light consumers of caffeine.\textsuperscript{52} In most experimental studies, however, neither a direct effect of caffeine consumption on mood nor a “restorative” effect following sleep restriction has been identified.\textsuperscript{45,53} There are few studies examining the effect of energy drinks specifically on mood in adults. For example, one study found energy drink consumption improved and/or maintained mood and performance during fatiguing and cognitively demanding tasks relative to placebo,\textsuperscript{54} but in another study in young adults, anxiety (but not depression) symptoms were associated with caffeine use, although only in males.\textsuperscript{55}

While there is also a common perception that caffeine has a positive effect on mood in youth, the empirical evidence in the pediatric population is scanty and is almost exclusively limited to adolescents and young adults. One exception is a case-control study in preadolescents (ages 9–12 y) that suggested that depressed children reported higher caffeine consumption than nondepressed children.\textsuperscript{56} Another study that found higher caffeine consumption in youth with major depressive disorder\textsuperscript{10} also reported increased anxiety with caffeine use, while a decrease in caffeine consumption was associated with treatment of depression. Dysphoric symptoms also appear to be associated with abstinence in high caffeine consumers.\textsuperscript{57}

### RECOMMENDATIONS FOR FUTURE RESEARCH

Given the relative scarcity of scientific data on caffeine consumption in the pediatric population, additional investigations are warranted and should include the following: 1) Document current rates of caffeine consumption across various pediatric groups and across different types of products; identify modifiable risk factors for caffeine use in various populations. 2) Identify specific gaps in knowledge and define reasons and expectations for use of energy drinks among a variety of pediatric consumer groups and correlate these with likelihood of use. 3) Explore the social context of caffeine consumption, including types of beverages, amounts, and timing of consumption. 4) Examine the effect of energy drink consumption on psychomotor and cognitive performance in children and adolescents, controlling for variables such as baseline rates of consumption and sleep-related impairments. 5) Assess the effects of highly caffeinated beverage consumption on sleep architecture in children, particularly as related to the effect on slow-wave and REM sleep. 6) Explore genetic factors that may influence caffeine consumption, caffeine efficacy, relative sensitivity of
consumers to the effects of caffeine, development of tolerance to caffeine, etc. For example, polymorphisms in the A2A Receptor gene/adenosine deaminase have been linked to individual differences in caffeine metabolism in adults. 7) Explore the influence of circadian factors, including circadian preference (i.e., “morningness” versus “eveningness”), on the extent and timing of caffeine consumption; for example, increased caffeine use has been linked to self-reported “evening type” compared to “morning type” in adolescents. 8) Document the short- and long-term effects of using caffeine as a substitute for sleep on health, performance, and safety outcomes.

CONCLUSION

Overall, relatively little is known about the short- and long-term health effects of energy drinks in the pediatric population, although the extent and frequency of use, as well as the variety of products consumed, appears to be on the rise in both school-aged children and adolescents. It is critical that further research be conducted to understand not only how much but also how and why energy drinks are being used in the pediatric population and to determine which internal (i.e., knowledge gaps, health beliefs, expectancies) and external (i.e., marketing, social pressures) factors have the most influence on decision making by consumers. In particular, the use of highly caffeinated products by adolescents in an attempt to mitigate the effects of chronic sleep loss may have significant repercussions for general health, performance, and safety. Moreover, the relationship between energy drink consumption and other unhealthy sleep behaviors (i.e., later bedtimes, excessive use of electronics) raises concerns about the detrimental effects of caffeine on sleep health.

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