Adolescent caffeine use and associated behaviors: Summary of latest research evidence

Alfgeir Logi Kristjansson, *PhD*
Associate Professor, West Virginia University, USA
Senior Researcher, ICSRA, Reykjavik University, Iceland

Jack E. James, *PhD*
Professor, Reykjavik University, Iceland

Collaborator/coauthor acknowledgement Dr. Jack E. James

Selected works

James, J. E. (1991). *Caffeine and health*. London: Academic Press

James, J. E. & Keane, M. A. (2007). Caffeine, sleep and wakefulness: Implications of new understanding about withdrawal reversal. *Human Psychopharmacology: Clinical & Experimental*, 22, 549-558.

James, J. E. (2014). Caffeine and cognitive performance: Persistent methodological challenges in caffeine research. *Pharmacology, Biochemistry and Behavior*, 124, 117-122.

Founding Editor-in-Chief: Journal of Caffeine Research, 2010 – 2015

Overview

1. Exposure: Brief history and current prevalence and products
2. Impact: Arousal, half-life, withdrawal and withdrawal reversal
3. Research among adults vs adolescents
4. Contemporary research among adolescents
5. Questions on health policy

Exposure: Brief history and current prevalence and products

History

- Caffeine has been a part of global history for thousands of years but was first isolated in its purest form in the 1820s
- The uniqueness of caffeine is that it transcends populations and time periods like no other substance, and is the most widely used psychoactive compound in history, >80% of the worlds population are habitual users
- Currently, caffeine is the only psychoactive compound widely available to, and even marketed directly at, children and youth

What is caffeine?

- A natural psychoactive stimulant that can be isolated from over 60 plants, or manufactured synthetically and added to food or diet
- Caffeine is a drug and shares traits with other addictive substances such as amphetamines and cocaine – and uses the same biochemical mechanisms as other drugs to stimulate brain and neurological function
- Repeated consumption leads to physical dependence, provoked by abrupt cessation of use

Common forms of dietary caffeine?*

- Coffee - ~ 100 mg (~240 ml/8oz)
- Black tea - ~ 50 mg per cup (~240 ml/8oz)
- Soda drinks (Cola, Mt. Dew) - ~35-55 mg per can (~350 ml/12oz)
- Energy drinks (Red Bull, Monster, etc) – ~ 80 mg per can (~240 ml/8oz)
- Energy "shots" (e.g. "5-hour energy") - ~ 200 - 242mg per bottle (60 ml/2oz)
- Dark chocolate – ~ 20 mg per 1 oz/~30 grams

Caffeine is also added to: Ice cream, Chewing gum, Yoghurt, Breakfast cereal, Cookies, Flavored milk, Over-the counter medications (e.g. for weight loss), Caffeine powder, Cosmetics (e.g. skin lotion)

- Most habitual users consume 100-600 mg per day

*Drewnowski and Rehm, 2016. *Nutrients*

Prevalence of use among children and youth?

- Adults: Overall, ~80%+ of population are daily habitual users
- Children and youth:

  Average use among 12-17 year olds: 50 mg per day *

  Average use among 14-19 year olds: 61 mg per day**

  Energy drink use on a steep rise***

*Ahluwalia and Herrick, 2015. Adv Nutr
**Drewnowski and Rehm, 2016. Nutrients
***Vercammen et al. 2019. Am J Prev Med

Impact: Arousal, half-life, withdrawal and withdrawal reversal

Caffeine impact

- Most use among adults is habitual and effects are benign
- Growing concern of high dosage use among children and youth
- Recent US-based study suggests that the overall caffeine consumption is similar to 10 years ago, but that high-dose use is more common than before, for example via “energy drinks”*
- Reports of caffeine overdose are regularly conveyed, including deaths OR deaths were caffeine was involved**

*Ahluwalia and Herrick, 2015. *Adv Nutr*
**James, 2012. *J Caff Res*

Withdrawal symptoms, and symptom cycle

Symptoms

- Headache
- Tiredness/fatigue
- Decreased energy
- Sleeplessness
- Drowsiness
- Difficulty concentrating
- Irritability
- Decreased cognitive performance
- Migraine symptoms

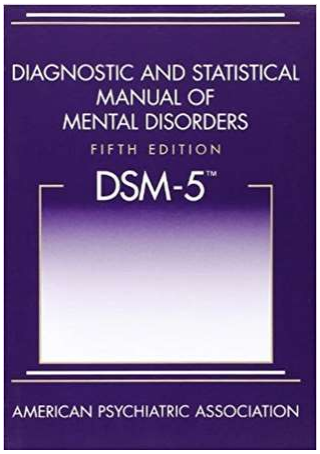
Typical symptoms cycle

- Symptoms can be produced with as little as one small cup of coffee daily (~80-100mg)
- Caffeine half-life: 2-9 hours (mean = 5 hours)
- Symptom initiation within 12-16 hours
- Peak around 24-48 hours
- Usually abate within 3-5 days but may persist up to 10 days

Caffeine disorders in DSM V

Latest DSM edition includes several clinically-relevant caffeine disorders

- Caffeine withdrawal
- Caffeine Intoxication
- Caffeine-Induced Anxiety Disorder
- Caffeine-Induced Sleep Disorder
- Caffeine-Related Disorder Not Otherwise Specified



In sum…

- Caffeine is a psychoactive compound with addictive properties
- Similar to use of other addictive substances caffeine use leads to withdrawal symptoms
- => Caffeine can be overused/abused
- Caffeine is readily available to children and youth

Withdrawal reversal: Issues with study designs

- Typical experimental studies sample healthy adults into experimental and control groups - similar to pharmacology studies
- **Most participants** are also habitual caffeine users (~80%+ of the population)
- Caffeine half-life: 2-9 hours, mean = 5 hours
- Overnight abstinence: ~10-14 hours

  $\Rightarrow$ Study design assumption: elimination of systemic caffeine by early morning
- Many placebo-controlled studies of caffeine make methodological convenience of natural overnight abstinence by simply asking participants to forgo their usual morning caffeine beverage prior to testing
- **This step**, intended to standardize procedures by ensuring participants are "equivalent" at time of caffeine administration, that has long been a cause of serious confounding*

*James, 2014. *Pharmacology, Biochemistry and Behavior*

The Multilayered Distinction between "Acute" and "Chronic" Exposure in Population Health

Exposure: "Acute" Benign and "Acute" Harmful

acute/modest exposure → benign

versus

acute/large exposure → harm

Exposure: "Acute" Benign and "Chronic" Harmful

acute/modest exposure → benign

versus

acute/modest exposure/lifelong/population-wide → harm

Research among adults vs children/adolescents

- A clear two-way distinction in the literature

- Children-Youth: Prevalence and risk behaviors – focus of today. Typically non-experimental designs
- Adults: "Benefits" of caffeine use, more often experimental design
  - For example, several observational studies in adults have found an inverse association between coffee drinking and mortality*

*James, 2018. *JAMA Internal Med*

Contemporary research among adolescents

- Prevalence and trend studies
- Sleep
- Health symptoms
- Academic achievement
- Alcohol use and alcohol mixed with energy drinks (AmED)
- Other substance use
- Anger, violence and other behavioral problems
- Complex pathways, mediation, bigger picture

Prevalence and trend studies

- Myriad of prevalence and trend studies conducted in recent years
  - Most concern energy drink consumption
- New study from NHANES data (National Health and Nutrition Examination Survey), 2003 – 2016*
  - Significant increase in energy drink consumption in all age groups (12-19 years, 20-39 years and 40-59 years)
  - Energy drink consumers had significantly higher total caffeine intake compared with non-consumers for adolescents (227.0 mg vs 52.1 mg, $p<0.001$)

*Vercammen et al. 2019. *Am J Prev Med*

Prevalence and trend studies, cont'd

- 62% of high school students report regular use*
- 2009: Between 2004 and 2009, energy drink sales increased by approximately 240% in the U.S. **
- Between 40%-60% of 18-20 year old college students report regular use, with 10% classified as high-frequency users (more than weekly)***
- Research overall suggests that use and sales have increased greatly since 2000

*Azagba et al. 2014. *Prev Med*
**Miyake and Marmorstein, 2015, *Add Behav*
***Patrick and Maggs, 2014, *J Adol Health*

Sleep

- Generally, caffeine intake negatively impacts sleep and increases daytime sleepiness
- Using validated measurement tools authors found that higher adolescent caffeine intake was related to*:
  - worse sleep quality
  - worse family sleep behaviors
- In a sample of 9th and 10th grade students in Iceland, authors found*:
  - A strong relationship between caffeine use and sleepiness
  - A moderate relationship between sleepiness and angry mood

*Pucci and Pereira et al. 2019. *J Child Adol Substance Abuse*
**James et al. 2011. *J Caff Res*

Sleep cont'd

- Caffeine use negatively related with sleep (insomnia) and positively related with daytime sleepiness*
- Greater caffeine consumption was negatively correlated with total sleep time on week nights**
- Children's caffeine use increases later sleep hours and poor sleep quality***

*Ludden and Wolfson, 2010. *Health Educ Res*
**Anderson and Juliano, 2012. *J Caff Res*
***Aepli et al. 2015. *Brain Sci*

Health symptoms and complaints

- In adults, caffeine use has repeatedly been found to increase systolic blood pressure
- Experimental study with Israeli youth found energy drink consumption to significantly increase systolic blood pressure in most participants within a brief period of time after consumption*

- Using a sample of 13 year old youth in Finland, authors found a linear dose-response association between energy drink consumption and various health complains such as head ache, sleeping problems, tiredness, and fatigue**

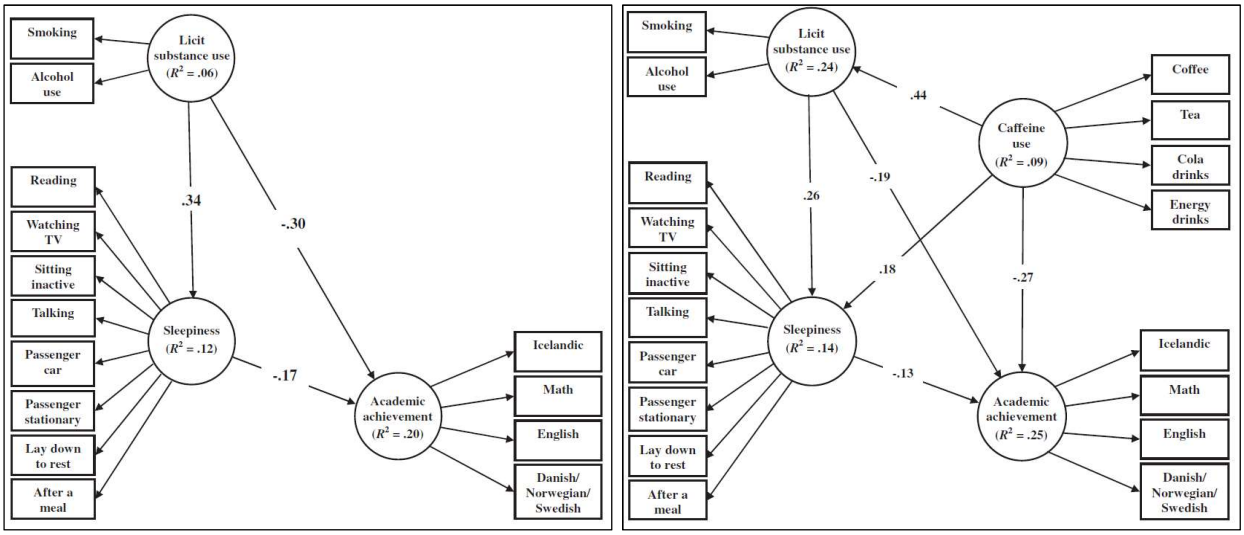
*Mansour et al. 2019. *Eur J Pediatr*
**Koivusilta et al. 2016. *Int J Public Health*

Health symptoms and complaints, cont'd

- Youth in Iceland data from 2013 with 10-12 year olds (N = 11,267) found:
  - Around 19% of boys and 8% of girls reported consuming cola drinks on a daily basis and 7% of boys and 3% of girls reported consuming energy drinks daily.
  - A general trend of a dose–response relationship was observed between never, less than daily, and daily consumption of both types of beverages and physical complaints such as headaches, stomach aches, sleeping problems, and low appetite
  - Variable relationships were generally stronger for energy drinks than cola drinks

*Kristjansson et al. 2014. *Prev Med*

Academic achievement



*James et al. 2011. *J Adol*

Alcohol use and alcohol mixed with energy drinks (AmED)

- Many studies have concluded that adolescent alcohol use is positively related to caffeine use, and consumption of energy drinks in particular

- Energy drink use positively predicted alcohol consumption in a longitudinal sample of 12-14 year olds*
- Energy drink and coffee consumption predicted later alcohol consumption, even after adjusting for other risk factors for alcohol consumption (e.g. parental monitoring)*

*Marmorstein, 2019. *Addictive Behav*

Alcohol mixed with Energy Drinks (AmED)

- By offsetting the sedating effects of alcohol, caffeine may reduce the sensation of intoxication, which in turn is likely to impair judgments about risky behavior (e.g., drunk-driving), and encourage higher consumption of alcohol, with further impairments to judgment and neurocognitive functioning*

- "…growing body of evidence, which indicates that compared to alcohol alone, the addition of caffeine increases the risk of engaging in unprotected sex, experiencing or committing sexual assault, driving while drunk, riding with an intoxicated driver, having an alcohol related motor vehicle crash, engaging in violence, and requiring
- medical treatment"*

*James, 2012. *J Caffeine Res* (Editorial)

Alcohol mixed with Energy Drinks (AmED), cont'd

Youth in Iceland junior college data, 16-17 year olds (N = 5,784)*

TABLE 1. Descriptive statistics for individual-level study variables by gender

	Boys			Girls		
Daily caffeine use glasses/cups	None %	One %	≥2 %	None %	One %	≥2 %
Coffee	79.6	14.0	6.4	84.1	13.3	2.6
Tea	82.1	14.9	3.0	72.9	22.6	4.5
Cola drinks	35.8	38.9	25.3	59.7	29.0	11.3
Energy drinks	72.8	21.1	6.1	86.0	11.8	2.2
Lifetime events	Never %	Once %	≥2 times %	Never %	Once %	≥2 times %
Drunkenness	56.4	11.6	32.0	55.0	11.9	33.1
AmED	64.9	15.4	19.7	60.2	18.8	21.0

*Kristjansson et al. 2015. *J Studies Alc Drugs*

Alcohol mixed with Energy Drinks (AmED), cont'd

TABLE 2. Model 1: Standardized and unstandardized regression weights for the multilevel SEM model including energy drink consumption

	Boys			Girls		
Individual-level relationships	Stand. β	Unstand. *b*	*SE*	Stand. β	Unstand. *b*	*SE*
Coffee → AmED	.23**	0.35	0.045	.17**	0.32	0.035
Tea → AmED	-.06*	-0.11	0.042	-.03	-0.05	0.035
Cola drinks → AmED	.08**	0.09	0.028	.11**	0.13	0.023
Energy drinks → AmED	.14**	0.20	0.052	.12**	0.24	0.048
Coffee → Drunkenness	.10**	0.52	0.075	.06**	0.39	0.062
Tea → Drunkenness	-.00	-0.02	0.075	.00	0.02	0.059
Cola drinks → Drunkenness	.02	0.05	0.055	.01	0.03	0.041
Energy drinks → Drunkenness	-.05**	-0.23	0.051	-.04*	-0.24	0.101
AmED → Drunkenness	.75**	2.45	0.061	.79**	2.55	0.053
School-level relationship	Stand. β		Unstand. *b*		*SE*	
AmED → Drunkenness	.88**		2.75		0.199	

Notes: SEM = structural equation modeling; stand. = standardized; unstand. = unstandardized; AmED = alcohol mixed with energy drinks.
*$p < .05$ (two tailed); **$p < .01$ (two tailed).

Mediation test showed a positive relationship between AmED and drunkenness for both genders

*Kristjansson et al. 2015. *J Studies Alc Drugs*

Other substance use

- Energy drink use among middle schoolers was assessed to predict tobacco smoking, alcohol use, and other drug use (N = 1,152)*
- Using odds ratios (OR), energy drink consumption positively predicted:
  - Smoking in last 12 months (Boys OR = 11.66, Girls OR = 8.17)
  - Alcohol use in last 12 months (Boys OR = 3.49, Girls OR = 8.58)
  - Ever drunkenness (Boys OR = 8.23, Girls OR = 3.84)
  - Ever marijuana use (Boys OR = 2.19, Girls OR = 4.51)**
  - Ever inhalant use (Boys OR = 2.39, Girls OR = 5.44)**
  - Ever prescription medication abuse (Boys OR = 1.43, Girls OR = 4.04)**

**only significant for girls*

*Mann et al. 2016. *Prev Med Reports*

Other substance use, cont'd

- Using data from 6th and 7th grade middle schoolers (N = 3,932), a cross-lagged path model was employed to assess the direction of variables relationship, one year apart

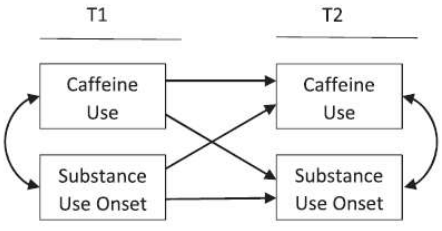


Figure 1 Cross-lagged path models (for demonstrative purposes, control variables are implied)

*Kristjansson et al. 2018. *Addiction*

Other substance use, cont'd

Table 3 Results from the final cross-lagged path model; caffeine with all outcomes.

DVs: caffeine at T2, smoking at T2, e-cigarettes at T2, alcohol at T2, drunk at T2	*Beta*	*Stand. Beta*	*SE*	*P*	*Model fits*
Caffeine at T1 > caffeine at T2	0.57	0.58	0.022	0.001	CFI = 0.980
Smoking at T1 > caffeine at T2	0.00	0.00	0.075	0.966	TLI = 0.941
E-cigarettes at T1 > caffeine at T2	0.10	0.05	0.075	0.184	RMSEA = 0.034
Alcohol at T1 > caffeine at T2	0.09	0.06	0.067	0.172	WRMR = 10.25
Drunk at T1 > caffeine at T2	−0.08	−0.04	0.083	0.323	
Caffeine at T1 > smoking at T2	0.54	0.23	0.073	0.001	
Smoking at T1 > smoking at T2	20.12	0.52	0.166	0.001	
E-cigarettes at T1 > smoking at T2	0.78	0.18	0.151	0.001	
Caffeine at T1 > e-cigarettes at T2	0.46	0.19	0.080	0.001	
E-cigarettes at T1 > e-cigarettes at T2	30.10	0.70	0.201	0.001	
Caffeine at T1 > alcohol at T2	0.42	0.18	0.087	0.001	
Alcohol at T1 > alcohol at T2	20.49	0.67	0.158	0.001	
Caffeine at T1 > drunk at T2	0.41	0.17	0.098	0.001	
Drunk at T1 > drunk at T2	20.21	0.43	0.229	0.001	
Alcohol at T1 > drunk at T2	10.00	0.27	0.163	0.001	

RMSEA = root mean square error of approximation; WRMR = weighted root mean square residual; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SE = standard error; DV = Dependent variables.

*Kristjansson et al. 2018. *Addiction*

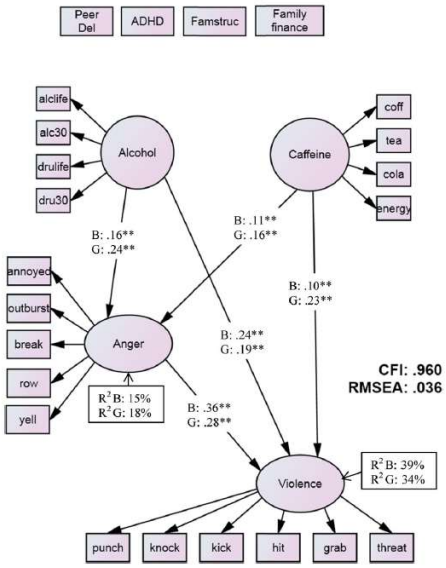
Anger, violence and other behavioral problems

- Several cross-sectional and other observational studies have found a positive relationship between adolescent caffeine use and anger and violent behaviors
- For example:
  - Using data from 10th grade youth in Iceland (N = 3,747), Kristjansson et al. found a robust additive explanatory power of caffeine for both violent behaviors and conduct disorders, after controlling for background factors, ADHD diagnosis and medication, peer delinquency, and substance use*

*Kristjansson et al. 2013. *J Youth Adol*

Complex pathways, mediation, bigger picture

- For example:
  - Using Icelandic data of 10th grade students (N = 3,670), James et al. found positive relations between caffeine use and both anger and violence among girls and boys with a particularly strong relationship for girls



*James et al. 2015. *Subst Use Misuse*

Complex pathways, mediation, bigger picture, cont'd

- Commonly, adolescent caffeine consumption is part of a more complicated process

- For example:
  - Excessive daytime sleepiness was associated with fewer healthy behaviors, while caffeine intake was a moderator in the relationship between daytime sleepiness and health behaviors*

*Pucci and Pereira et al. 2019. *J Child Adol Substance Abuse*

Questions on health policy

- Should there be any form of regulation on caffeine or energy drinks?
- Caffeine-related harm occurs. This is now well established. But is it prevalent enough to consider regulation?
- For example, for children, adolescents, pregnant women, the elderly, other subgroups at risk?

What kind of policy?

- Age restrictions on sale? How enforced?
- The form and content of labeling of products that contain caffeine? Effective?
- Restrictions on advertising?
- Taxation policies and/or other financial measures of the kind believed to have been effective in curtailing cigarette smoking and alcohol use

Thank you!

Dr. Alfgeir Logi Kristjansson
alkristjansson@hsc.wvu.edu