

Adolescent Caffeine Consumption and Self-Reported Violence and Conduct Disorder

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Abstract Caffeine is the most widely used psychoactive substance in the world and currently the only one legally available to children and adolescents. The sale and use of caffeinated beverages has increased markedly among adolescents during the last decade. However, research on caffeine use and behaviors among adolescents is scarce. We investigate the relationship between adolescent caffeine use and self-reported violent behaviors and conduct disorders in a population-based cross-sectional sample of 3,747 10th grade students (15–16 years of age, 50.2 % girls) who were enrolled in the Icelandic national education system during February 2012. Through a series of multiple regression models, while controlling for background factors, Attention Deficit Hyperactivity Disorder symptoms and current medication and peer delinquency, and including measures on substance use, our findings show robust additive explanatory power of caffeine for both violent behaviors and conduct disorders. In addition, the association of caffeine to the outcomes is significantly stronger for girls than boys for both violent behaviors and conduct

disorders. Future studies are needed to examine to what extent, if at all, these relationships are causal. Indication of causal connections between caffeine consumption and negative outcomes such as those reported here would call into question the acceptability of current policies concerning the availability of caffeine to adolescents and the targeting of adolescence in the marketing of caffeine products.

Keywords Adolescents · Caffeine · Conduct disorders · Violent behavior · Iceland

Introduction

Caffeine is historically and contemporarily the most widely used psychoactive substance in the world (James 2012). Caffeine is also the only psychoactive substance legally available to children and adolescents, a growing population of users in the Western world during last decade and a half (Temple 2009). A study by the National Sleep Foundation estimated that about 75 % of high-school aged adolescents in the U.S. drink at least one caffeinated beverage every day (2006), and several other studies have shown comparable rates (Anderson and Juliano 2012; Kristjansson et al. 2011; Ludden and Wolfson 2010). Although the growth in popularity of caffeine among adolescents has elicited expressions of concern both in the scholarly literature and in popular media, few systematic studies have been conducted.

Physiologically, caffeine has short-term effects on the nervous system potentially affecting mood and behavior (James 1997). It exerts a variety of pharmacological actions at diverse sites, both centrally and peripherally, that are generally believed to be the result of a

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competitive blockade of endogenous adenosine (Dunwiddie and Masino 2001). Similar to other substance use, caffeine consumption frequently produces physical dependence with associated withdrawal symptoms (e.g., headache, tiredness, and irritability) (Strain et al. 1994). In addition, several reports have appeared in the popular media about instances linking caffeine use among young people to injury and even death (Charles 2012; Meier 2012). These media stories along with reviews and commentaries in the pediatric literature have raised concerns about caffeine use and potential implications for child and adolescent health and behaviors (Fogger and McGuinness 2011; Pennington et al. 2010; Schneider et al. 2011; Seifert et al. 2011). Thus, research related to child and adolescent caffeine use and health-related outcomes is urgently needed.

The most common forms of caffeine consumption among children and youth are sugar-sweetened beverages (SSBs) such as soda (30–55 mg of caffeine per 12 oz/355 ml) and more recently so-called “energy drinks”, many of which are characterized by a much higher concentration of caffeine (70–130 mg caffeine per 12 oz/355 ml) than traditional soda, and are marketed specifically for young people (Arria and O’Brien 2011; Oddy and O’Sullivan 2009). By comparison, a regular 1 oz/30 ml espresso coffee contains 40–75 mg of caffeine and generic brewed 12 oz/355 ml cup of coffee from 145 to 250 mg of caffeine (Mayo Clinic 2011). The sale and consumption of energy drinks have increased markedly during the last decade and represent a multi-billion dollar business in the US alone (Reissig et al. 2009).

Present Knowledge

Although caffeine has been studied for many decades in adults (James 2010), research involving adolescents remains very limited in scope. Regular large scale and nationally representative surveillance surveys such as the European School Project on Alcohol and other Drugs (ESPAD) (Hibell et al. 2012) that is conducted among 30–40 European countries every 3–4 years (the last one in 2011), and the Centers for Disease Control’s annual Youth Risk Behavior Surveillance survey in the US (Eaton et al. 2012), have not included measurements of caffeine use. The only nationally representative study among adolescents that we know of that has included measurements of caffeine use is the 2009 *Youth in Iceland* school survey (James et al. 2011; Kristjansson et al. 2011). A recent publication from that study showed through path analyses that caffeine use was a strong and positive predictor of daytime sleepiness and licit substance use, and was strongly and negatively related to academic achievement (James et al. 2011). In a separate

analysis from the same cohort, Kristjansson et al. (2011) found similarly strong effects for angry mood. Despite the relationship between caffeine use and anger among adolescents, no study has looked into the relationship between caffeine and negative behaviors such as violence or conduct disorder.

Currently there is a scarcity of enquiries into adolescent caffeine use and outcomes on the population level. Most published studies have operated with small samples and have focused on particular aspects of use and associated outcomes such as the use of energy drinks (Velazquez et al. 2012), the mixing of energy drinks and alcohol (Marczinski et al. 2011), withdrawal symptoms (Luebbe and Bell 2009), sleep problems (Calamaro et al. 2012), and certain emotions (Babu et al. 2008; Penolazzi et al. 2012). Caffeine use among youth and young people also has been shown to be related positively to Attention Deficit Hyperactivity Disorder (ADHD) symptoms and diagnosis (Martin et al. 2008), smoking (Walker et al. 2010), marijuana use (Miller 2008) and composite measures of substance use (James et al. 2011; Kristjansson et al. 2011). Whether caffeine has implications to aggressive behaviors, such as conduct disorders and violent behaviors on the population level, is not known, and neither is the interplay between caffeine and aggressive behaviors when taking account of substance use and ADHD symptoms.

Conduct Disorders and Violent Behaviors

Conduct disorders typically are defined as the violation of major rules, social norms and even laws (Murray and Farrington 2010). Several interrelated factors that also have been shown to be related to caffeine use have been found to contribute to the likelihood of conduct disorders, and in multiple populations. Those include substance use (Lynne-Landsman et al. 2011), delinquency (Wang et al. 2012), peer delinquency (Benson and Buehler 2012; Keijsers et al. 2012) and ADHD symptoms (Beauchaine and Gartner 2003; Walther et al. 2012). Violence among adolescents usually is defined with behaviors such as punching, kicking, shoving and/or hitting others (Bernburg et al. 2009). Although often studied separately, conduct disorders and violent behaviors also are constructs that are interrelated strongly (Henggeler and Sheidow 2012). Therefore, and unsurprisingly, a similar picture has been painted with regards to violent behaviors. Adolescent engagement in violence is predicted by substance use (Marcus and Jamiison 2013; Salas-Wright et al. 2012), peer delinquency (Rees and Pogarsky 2011; Reingle et al. 2012) and ADHD symptoms (Bernat et al. 2012). In the light of increase in access and heightened prevalence in the use of caffeinated beverages among adolescents (Pomeranz 2012), more research on its effects recently has been called for (Arria

and O'Brien 2011; Temple 2009). Currently little is known in how adolescents' consumption of caffeine plays a role in the reported relationships between substance use and peer delinquency to violence and conduct disorders. Given that caffeine stimulates the central nervous system and causes multiple withdrawal symptoms, it seems logical that it may also have implications to aggressive behavioral outcomes. We propose to look further into this notion.

The Current Study

To date, no studies have been published that focus exclusively on adolescent caffeine use and violence and conduct disorder. With the reported physiological and behavioral effects of caffeine (James 2010) and current and recent increase in access and use among adolescents (Pomeranz 2012), we conducted a population study that examines the relationship between caffeine use and violent behaviors and conduct disorder among adolescents.

The first aim of the present study was to examine whether caffeine use is related to violent behaviors and conduct disorders while accounting for background measures such as SES, gender, and ADHD symptoms and peer delinquency. Consistent with Kristjansson et al. (2011) we hypothesized that caffeine is positively related with both violent behaviors and conduct disorders while controlling for the aforementioned factors.

The second aim of this study was to examine whether the relationship between adolescent caffeine use and violent behaviors and conduct disorders is different for boys and girls. This we put forth as a more exploratory part of the study since we do not know of any research finding that suggests this to be the case. Although the Kristjansson et al. (2011) study revealed a significant gender difference in explained variance for angry mood, the strength of the relationships to caffeine were similar for boys and girls.

The third aim of our study was to test if substance use masks out the proposed relationship between caffeine use and violent behaviors and conduct disorder. Such a finding would suggest that caffeine consumption and other substance use covary in relationship to aggressive behaviors, but not that caffeine use provides additive explanation to these behaviors. Because adolescent caffeine use has been shown to be positively associated with various forms of substance use (James et al. 2011; Miller 2008; Walker et al. 2010), we hypothesized that both caffeine use and substance use are related positively to both violent behaviors and conduct disorder and that caffeine use retains its positive relationship to both constructs after controlling for substance use. In addition, we explore whether the constructs of caffeine use and substance use interact in their relationship to violent behaviors and conduct disorder.

Methods

Sample and Procedures

The data for this study came from the latest of the population-based *Youth in Icelandic* surveys. This sample includes 10th grade students, aged 15–16 years, who were enrolled in Icelandic secondary schools during February 2012. The study respondents represent approximately 85 % of the national population of Iceland in these age groups. All aspects of data collection were supervised by the Icelandic Centre for Social Research and Analysis (ICSRA) at Reykjavik University and carried out with passive parental consent using procedures approved by the Icelandic authority overseeing the protection of human research subjects. ICSRA distributed anonymous questionnaires and envelopes for returning completed questionnaires to all secondary schools in Iceland. Consistent with published study protocols (Kristjansson et al. in press; Sigfusdottir et al. 2009), teachers at individual school sites supervised the participation of the students in the study and administered the survey questionnaire. All students who attended school on the day that the questionnaire was scheduled to be administered completed the questionnaire. Students were instructed not to write their names, social security numbers, or any other identifying information anywhere on the questionnaire. Once completed students were asked to place their completed questionnaire in the sealed envelope provided before returning it to the supervising teacher. A total of 3,747 students in 10th grade (50.2 % girls) completed the questionnaire.

Measures

Table 1 displays the descriptive statistics for all study variables.

Table 1 Descriptive statistics for all study variables

	N	Min	Max	Mean	SD
Violent behaviors	3,561	0.00	3.61	0.92	1.08
Conduct disorders	3,595	0.00	2.94	0.65	0.68
Caffeine use	3,465	0.00	3.33	0.66	0.64
Substance use	3,525	0.00	2.94	0.65	0.81
Gender	3,644	0.00	1.00	0.50	0.50
Family structure	3,660	0.00	1.00	0.31	0.46
Parental education	3,521	2.00	12.00	7.77	2.84
Family financial status	3,616	1.00	7.00	4.65	1.12
ADHD diagnosis	3,619	0.00	1.00	0.12	0.32
Current ADHD medication	3,617	0.00	1.00	0.05	0.22
Peer delinquency	3,550	0.00	3.43	0.46	0.76

Caffeine Use

Our caffeine measure was pilot tested in 2009 (James et al. 2011) and found to cover adequately the consumption of caffeinated beverages among Icelandic adolescents in a population-based health and behavior survey. Respondents were asked about their daily caffeine consumption with the question, “How many glasses or cups do you consume every day” of coffee, tea, cola drinks, and energy drinks that contain caffeine (e.g., Red Bull or Magic). Response options were 0 = “none”, 1 = “one glass/cup”, 2 = “two glasses/cups”, 3 = “three glasses/cups”, 4 = “four glasses/cups”, 5 = “five glasses/cups”, and 6 = “6 glasses/cups or more”. It should be mentioned that de-caffeinated coffee and tea are infrequently consumed in Iceland, making it unlikely that respondents were referring to such alternatives when reporting coffee and tea consumption. In order to potentially increase the precision of our caffeine measure and consistent with published estimates of the caffeine content of beverages (Chou and Bell 2007; McCusker et al. 2006) we weighted the caffeine variables to better reflect the differences between them regarding amount of caffeine consumed. This was done by multiplying the question on tea drinking by 0.5, the question on cola drinks by 1.0 and the two questions on coffee and energy drinks by 1.5.

Substance Use

We constructed a measure with three questions headed “How often, if ever, in your lifetime, have you?” (1) smoked cigarettes, (2) had a drink of alcohol of any kind, and (3) used marijuana. The response format was: 0 = “never”, 1 = “1–2 times”, 2 = “3–5 times”, 3 = “6–9 times”, 4 = “10–19 times”, 5 = “20–39 times”, 6 = “40 times or more”. The questions were summed to form a scale (Cronbach’s Alpha = .77).

Gender

Gender was measured with questions about the respondent’s sex and coded 0 = “boys” and 1 = “girls”.

Family Structure

Family Structure was measured with the question “Which adults live in your home with you” and the following response categories: 1 = “my father and mother”, 2 = “I live separately but equally with my mother and father”, 3 = “I live mainly with my mother”, 4 = “I live mainly with my father”, 5 = “my mother and her partner”, 6 = “my father and his partner”, 7 = “I live on my own”, 8 = “I live in different arrangements”. The questions were

collapsed to the following categories: “lives with both biological parents” = 0 (68.6 %) and “lives in different arrangements” = 1.

Parental Education

Information on parental education was obtained by asking respondents separate questions about their fathers’ and mothers’ educational attainment. Response options were 1 = “finished elementary school or less”, 2 = “started but did not finish secondary school”, 3 = “finished secondary school”, 4 = “started university but did not finish”, and 5 = “has a university degree”, 6 = “Don’t know”. The two questions were summed to form a scale ranging from 2 to 12.

Family Financial Status

The financial status of the family was assessed with the question “What do you think is the relative financial standing of your family in comparison to other families in Iceland?” and the following response categories: 1 = “much worse off”, 2 = “considerably worse off”, 3 = “a little worse off”, 4 = “similar to others”, 5 = “a little better off”, 6 = “considerably better off”, and 7 = “much better off”.

ADHD Diagnosis and Medication

ADHD diagnosis and current medication use was measured with the following two questions: “Have you ever been formally diagnosed with ADHD?”, and “Are you currently taking medication for ADHD that has been prescribed to you”. Response categories were 0 = “No”, and 1 = “yes”. Eleven point seven per cent of participants in our sample have been diagnosed with ADHD at some point in their life and 5.1 % are currently taking medication for the disorder.

Peer Delinquency

We measured peer delinquency with 5 questions developed by the Institute for Educational Research in Iceland (IER), the predecessor to ICSRA, and recently shown to have adequate internal consistency in Icelandic and European samples (Sigfusdottir et al. 2012). Similar items have been widely used to measure peer delinquency (e.g., Heimer and Matsueda 1994; Thorlindsson and Bernburg 2006). The question heading was “How often do you believe any of your friends have done the following during last 12 months?”, and the questions: (1) stolen something worth less than 5,000 ISK (~\$ 40), (2) stolen something worth more than 5,000 ISK (~\$ 40), (3) exerted violence

in order to rob or steal, (4) broken into a building or a car to steal, and (5) damaged or vandalized things that did not belong to you. The response format was the same as with the questions on violent behaviors and were summed to form a scale (Cronbach's Alpha = .80).

Interaction Terms

Interaction variables for caffeine use and gender and caffeine use and substance use were constructed by multiplying the caffeine use measure first with gender and secondly with substance use. Prior to these multiplications we mean centered the untransformed caffeine variable to overcome the problem of inflated errors and found that the variance inflation factor was below the suggested threshold of 4.0 in all our models (Gujarati 2003).

Violent Behaviors

Violence is measured with six questions that were originally developed by the IER. They have previously shown adequate internal consistency both in Icelandic and several European samples (Sigfusdottir et al. 2012). The questions are headed with "How often during the past 12 months have you done any of the following?" and the subsequent options: (1) punched somebody, (2) knocked somebody over, (3) kicked somebody, (4) hit or slapped somebody, (5) grabbed someone by the neck, (6) threaten someone with violence. The response format was 0 = "never", 1 = "once", 2 = "2–5 times", 3 = "6–9 times", 4 = "10–13 times", 5 = "14–17 times", 6 = "18 times or more". The scores were summarized to form a scale (Cronbach's Alpha = .91).

Conduct Disorders

For conduct disorder, we used the *Oregon adolescent depression project conduct disorder screen* (OADP-CDS) (Lewinsohn et al. 2000). This is a six item scale headed with: "How often during the past 12 months have you done any of the following?" and the questions: (1) broken the rules at home, (2) broken the rules in school, (3) got into fights, (4) truancy, (5) run away from home, (6) got into trouble for lying or for stealing. The response format was 0 = "almost never or seldom", 1 = "a few times or sometimes", 2 = "quite often or often", 3 = "almost all the time or all the time". The scores were summarized to form a scale (Cronbach's Alpha = .78).

Data Analysis

An estimated 90 % of the approximately 320,000 inhabitants of Iceland are of Norse-Celtic decent, around 77 % of

the population belongs to the Lutheran State Church, close to 5.0 % are outside religious institutions, and no other religious sect has more than 3.3 % of the population registered in its services (Statistics Iceland 2012). Because of this homogeneity, exogenous variables such as race and religion, which are often used in research in other countries, were not included in the present analysis.

Due to high skew and kurtosis in the measures on caffeine use, substance use, violent behaviors and conduct disorders their distributions were transformed using the natural logarithmic function, which brought the scores into the suggested range of ± 1.0 on all occasions (Gujarati 2003). The same method of transformation was applied to the measure of peer delinquency which brought the skew and kurtosis scores down to 1.59 and 1.67, respectively.

The main method of analysis we used was multiple linear regression with interaction terms (Gujarati 2003). We ran five separate models in a hierarchical order within each dependent variable to better understand the interplay between caffeine, gender, and other substance use. We report adjusted R^2 for all models and statistically test for changes in variance explained between them. In order to increase precision in our multivariate analyses, we identified a primary variable list that includes all variables used in the fifth and final models on both occasions. This approach results in the same listwise deletion of respondents for all subsequent models within both dependent variables and therefore the same N for all analyses.

Results

The most common form of caffeine use in our sample was cola drinks (51.5 % daily use) followed by energy drinks (20.2 % daily use). A total of 63.0 % of study participants report consuming some form of caffeine on a typical day. With regards to substance use 20.5 % of our sample claim to have smoked a cigarette once or more in their lifetime, 47.6 % have had a drink of alcohol at some point in their life, and 6.6 % have used marijuana once or more.

Predicting Violent Behaviors

The multivariate analyses predicting violent behaviors are depicted in Table 2. Model 1 shows that girls are less likely than boys to engage in violent behaviors (standardized beta = .27) and peer delinquency is also strongly related to violent behaviors. The second Model adds caffeine to the equation and reveals a robust additive explanation to equation 1 (standardized beta = .19). The third Model shows that the relationship between caffeine and violent behaviors is significantly stronger for girls than boys, as evident by the interaction variable caffeine*gender. The fourth Model adds

Table 2 Standardized and unstandardized beta coefficients from OLS regression models predicting violent behaviors

	Model 1		Model 2		Model 3		Model 4		Model 5	
	B (SE)	β								
Gender	-.57 (.34)	-.27***	-.48 (.03)	-.23***	-.48 (.03)	-.23***	-.51 (.03)	-.24***	-.51 (.03)	-.24***
Family structure	.03 (.04)	.01	.01 (.04)	.00	.01 (.04)	.00	-.06 (.04)	-.02	-.06 (.04)	-.02
Parental education	-.02 (.01)	-.01	-.01 (.01)	-.02	-.01 (.01)	-.02	.00 (.01)	.00	.00 (.01)	.00
Family financial status	-.02 (.02)	-.02	-.02 (.02)	-.02	-.02 (.02)	-.02	-.01 (.02)	-.01	-.01 (.02)	-.01
ADHD diagnosis	.17 (.67)	.05**	.11 (.07)	.03	.10 (.07)	.03	.03 (.06)	.01	.03 (.06)	.01
ADHD medication	.19 (.10)	.04	.16 (.10)	.03	.17 (.10)	.03	.18 (.09)	.03	.16 (.09)	.03
Peer delinquency	.48 (.02)	.34***	.43 (.02)	.30***	.43 (.02)	.30***	.33 (.02)	.24***	.33 (.02)	.23***
Caffeine			.31 (.03)	.19***	.25 (.02)	.15***	.17 (.03)	.10***	.11 (.04)	.07***
Caffeine*gender					.06 (.02)	.07**	.04 (.02)	.05*	.04 (.02)	.05*
Substance use							.29 (.02)	.22***	.28 (.02)	.22***
Caffeine*substance use									.01 (.01)	.05*
Adjusted R ²	.23		.26		.26		.30		.30	
F for R ² change	128.7***		157.8***		11.5***		157.8***		4.5*	

* $p < .05$; ** $p < .01$; *** $p < .001$

substance use to the equation. Although substance use is strongly related to violent behaviors (standardized beta = .22) the effects of caffeine is still quite strong among boys (standardized beta = .10) and still significantly stronger for girls (standardized betas = .10 + .05 = .15) as was the case in Model 3. The fifth and final Model shows that the relationship between substance use and violent behaviors is conditioned by caffeine to a small degree, as revealed by the significant caffeine*substance use variable. Variance explained increases significantly throughout the five models with the greatest increase for caffeine in Model 2 (3.1 %) and substance use in Model 4 (3.5 %).

Predicting Conduct Disorders

The multivariate models predicting conduct disorders are shown in Table 3. Model 1 shows that girls are slightly less likely than boys to contend with conduct disorders (standardized beta = .09), having ADHD diagnosis is positively related with conduct disorders (standardized beta = .12) and peer delinquency is strongly related to conduct disorders (standardized beta = .36). The second Model shows a strong relationship between caffeine use and conduct disorders (standardized beta = .22), and as with the violent behavior Models in Table 2, this relationship is stronger for girls than boys as indicated by the significant interaction variable for gender in Model 3. As before, substance use was added to the equation in Model 4. Although substance use is very strongly related to conduct disorders (standardized beta = .33) the effects of caffeine is still quite strong among boys (standardized beta = .10) and remains significantly stronger for girls (standardized betas = .10 + .05 = .15) as in predicting violent behaviors. The fifth and final Model shows that the relationship between substance use and conduct disorders is not conditioned by caffeine or vice versa. Except for Model 5, variance explained increases significantly across all models with the greatest increase for caffeine in Model 2 (4.1 %) and substance use in Model 4 (7.8 %).

Discussion

This study sought to examine whether caffeine use is related to violent behaviors and conduct disorder in a nationally representative sample of 15–16 year old adolescents. Consistent with the first study aim, our findings indicate that caffeine use among adolescents is strongly related to both violent behaviors and conduct disorder when accounting for differences in background factors, ADHD diagnosis and current medication, and peer delinquency. The second research question proposed to look at potential gender differences of these findings. Somewhat surprisingly, we consistently found a stronger relationship

Table 3 Standardized and unstandardized beta coefficients from OLS regression models predicting conduct disorders

	Model 1		Model 2		Model 3		Model 4		Model 5	
	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Gender	-.12 (.02)	-.09***	-.06 (.02)	-.04*	-.05 (.02)	-.04*	-.08 (.02)	-.06***	-.08 (.02)	-.06***
Family structure	.09 (.02)	.06***	.07 (.02)	.05**	.07 (.02)	.05**	.01 (.02)	.01	.01 (.02)	.01
Parental education	-.00 (.00)	-.02	-.00 (.00)	-.02	-.00 (.00)	-.02	.00 (.00)	.00	.00 (.00)	.00
Family financial status	-.03 (.01)	-.05**	-.03 (.01)	-.05**	-.03 (.01)	-.05**	-.02 (.01)	-.04**	-.03 (.01)	-.04**
ADHD diagnosis	.26 (.04)	.12***	.21 (.04)	.10***	.20 (.04)	.09***	.14 (.04)	.07***	.14 (.04)	.07***
ADHD medication	.14 (.06)	.04*	.12 (.06)	.04*	.13 (.06)	.04*	.13 (.06)	.04*	.13 (.06)	.04*
Peer delinquency	.32 (.02)	.36***	.28 (.01)	.32***	.28 (.01)	.31***	.19 (.02)	.21***	.19 (.02)	.21***
Caffeine			.23 (.02)	.22***	.18 (.02)	.17***	.10 (.02)	.10***	.09 (.03)	.08***
Caffeine*gender					.05 (.01)	.08***	.03 (.01)	.05**	.03 (.01)	.05**
Substance use							.27 (.01)	.33***	.27 (.14)	.32***
Caffeine*substance use			.23				.31		.00 (.00)	.03
Adjusted R ²	.19		.23		.23		.31		.31	
F for R ² change			F (1,3134) = 167.3***		F (1,3133) = 15.0***		F (1,3132) = 354.0***		F (1,3131) = 1.5	

* $p < .05$; ** $p < .01$; *** $p < .001$

between caffeine use and both violent behaviors and conduct disorders among girls. In the light of our third research question, we found that substance use is strongly related to both violent behaviors and conduct disorder. On the other hand, the relationship between caffeine use and both outcomes remained significant after the inclusion of substance use, which underlines the additive explanatory importance of caffeine to violent behaviors and conduct disorders. Finally, the exploratory research question pertaining to the interaction effects between caffeine use and substance use shows a small significant association to violent behaviors but such a relationship was not found for conduct disorder.

In our study, girls who frequently consume caffeinated beverages were more likely than girls who do not consume such beverages to report engaging in violent behaviors or to suffer from conduct disorders, and they are also more likely to report these behaviors than boys who either use caffeine or not. The fact that stronger relationships between caffeine and both conduct disorders and violent behaviors were observed for girls than for boys may be explained in-part by research that has documented different physiologic response to caffeine among males and females. Research has suggested that females have the potential to be differentially impacted by caffeine compared with males, due to their higher percentage of body fat in addition to hormone cycles (Graham and MacLean 1998). More recently, a study with girls and boys in Buffalo (Temple et al. 2010) found that boys had a stronger physiologic response to caffeine (higher blood pressure) than girls. Thus, future research should examine the relationship between caffeine and aggressive behaviors while also accounting for body mass index. An alternative explanation for our observed gender difference may be due to dissimilarities in prevalence. Caffeine use is considerably more common among boys than girls (James et al. 2011; Kristjansson et al. 2011). Therefore, it may be that the overall impact of usage is more general across the board among boys than girls and that girls who regularly use caffeine represent a more distinct group of users among girls overall than caffeine using boys do among all boys. This explanation remains to be studied further.

The relationship between substance use and both violence and conduct disorder has been well established (Lynne-Landsman et al. 2011; Marcus and Jamison 2013). Our findings that caffeine is related significantly to both of these behavioral constructs before and after the inclusion of substance use in our models suggests that caffeine plays a distinct role from substance use in explaining violent behaviors and conduct disorder. On the other hand, the small but significant interaction relationship between caffeine use and substance use on violent behaviors suggests that, together, they have greater effects on our outcomes than as separate constructs. This is not surprising since

studies have shown that adolescents often use caffeine in conjunction with other substances (James et al. 2011; Miller 2008) and even consume it mixed together with alcohol, for example with the use of energy drinks (Marczinski et al. 2011).

As a background check to our data, and to confirm that our findings are not due to the result of a small subgroup of participants who both use caffeine heavily and exhibit more violent behaviors and conduct disorder, we ran separate analyses with standardized and unstandardized variables and the saved residuals from our multivariate models (data not shown). Neither suggests a cluster of outliers that is responsible for our findings. In addition, as a validity check to our weighted caffeine measure, we ran our models both with the weighted and unweighted caffeine construct and found a minor increase in the association between caffeine and the outcome variables in the weighted measure. This is expected as the weighted measure should better reflect the caffeine impact on the respondents.

The present findings have several implications for future research. Measurements of caffeine consumption should be included in studies on adolescent risk behaviors and associated factors. By doing so, researchers will be able to come closer to explaining the relative impact of alcohol and substance use as two obvious examples. Another important and previously unpublished finding is the gender difference that emerged from the models that were tested. Caffeine was a significantly stronger predictor of both violent behaviors and conduct disorders among girls. In a previous publication by our group, we showed through structural equation modeling, controlling for substance use, sleep and parental factors, that adolescent caffeine use is related strongly to angry mood but not to a significantly greater extent for either gender (Kristjansson et al. 2011). Together with the present findings, this underlines an important future study area, namely, the interplay between caffeine, anger, and negative behaviors such as violence and conduct disorders.

Overall, given the lack of legal regulation around the content of caffeine in beverages, as well as the absence of policy around its use among children and adolescents (Pomeranz 2012; Temple 2009), more research into the nature and patterns of use is needed. There is a particular scarcity and need for further development concerning measurements of adolescents' caffeine consumption. In this study, we used a relatively straight forward and simple method of accounting for differences in caffeine amount in different beverages and were able to find a slight increase in caffeine effects for the weighted measure. There is also a particular need for longitudinal research into developmental patterns of caffeine use. Whether caffeine precedes the use of other mood altering substances or merely co-occurs with their use is not known and neither is the question about the exacerbating impact of caffeine use on

behavioral outcomes such as the ones presented in this study. The current findings merely establish that such a relationship exists.

This study has several limitations but also several strengths. Our findings are based solely on cross-sectional data rendering implications regarding cause and effect difficult. Second, as discussed, our caffeine measure is a less than precise estimation of amount of caffeine consumed, because caffeinated beverages vary greatly in size and caffeine concentration. Third, our findings are based on self-reports that have not been independently verified. Apart from these limitations, our study also has several strengths. Our sample was large and representative of the national population. Second, the data were collected in schools with a well-established and consistent methodology that the ICSRA has been utilizing for over a decade and a half. Third, partly because of the large sample size, we were able to control for a wider range of potential confounders than has been possible in previous studies.

The findings of the present study show a robust explanatory power of caffeine use in violent behaviors and conduct disorder among adolescents. Future studies are needed to examine to what extent, if at all, the relationships observed in this study between caffeine and these important adolescent outcomes are causal. Indication of causal connections between caffeine consumption and negative outcomes such as violent behaviors and conduct disorders (for example using repeated-measures longitudinal designs) would call into question the acceptability of current policies concerning the availability of caffeine to adolescents and the targeting of adolescence in the marketing of caffeine products.

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Author contributions ALK conceived the study, conducted the initial literature review and designed and carried out the statistical analyses as well as contributing substantially to the writing. IDS participated in the design and writing of the paper, oversaw the ICSRA data collection, and reviewed multiple versions of the manuscript. SSF contributed to the design, writing and formatting of the paper and reviewed multiple versions of the manuscript. JEJ wrote parts of the introduction and discussion sections, reviewed multiple versions of the manuscript, and contributed to the analyses. All authors read and approved the final manuscript.

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