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Adolescent Caffeine Consumption, Daytime Sleepiness, and Anger

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Introduction: Caffeine use has been increasing among adolescents and young adults but much remains to be known about the consequences and context of their use.

Methods: With self-reported anger as the key outcome variable, 7348 Icelandic adolescents were surveyed for caffeine consumption, cigarette smoking, alcohol use, daytime sleepiness, and potential confounders. Structural equation modeling was used to examine direct and indirect effects of seven latent constructs: parental education, parental support, peer support, caffeine consumption, licit substance use (nicotine and alcohol), sleepiness, and anger; and two direct effects were measured using variables for family structure and family financial status.

Results: Daily caffeine consumption was reported by 76.3% of participants, and of the four caffeine beverages surveyed, cola drinks were most often consumed, followed by energy drinks, tea, and coffee. Boys reported more caffeine use on average than girls, with the difference being particularly marked for consumption of cola and energy drinks. Girls reported significantly more sleepiness and more anger symptoms overall than boys, but there were no gender differences on the measures of cigarette smoking and alcohol consumption. Amount of caffeine consumed was strongly associated with other substance use (nicotine and alcohol) and strongly associated with daytime sleepiness. Structural equation modeling showed that a substantial proportion (43% for girls and 48% for boys) of the total relationship between caffeine and anger was due to mediation through sleepiness and licit substance use.

Conclusion: High prevalence of daily caffeine consumption and the strength of the observed associations between caffeine and other important biobehavioral and psychosocial variables demonstrate the importance of including measurements of caffeine consumption in future studies of adolescent adjustment and development.

Introduction

There is a long tradition of concern about the possible detrimental effects of early use of substances on adolescent development and adjustment and the consequential potential for long-term negative physical, psychological, and social outcomes.[1,2] Being the period of transition from childhood to adulthood, adolescence is fraught with novel challenges arising from changing biology and life roles, emerging aspirations, and new responsibilities, often characterized by emotional turmoil and volatility. Because brain structures involved in the regulation of emotion are among the last to mature, not fully developing until a decade after mid-adolescence,[3] substance use during adolescence poses risks for emotional development and regulation.[3,4] In particular, levels of anger during adolescence have been found to predict physical and psychological health as well as levels of substance use and risk behaviors during adolescence and in adulthood.[5–7]

Among the licit and illicit substances used by adolescents, nicotine and alcohol appear to have attracted the most research attention. This may be due to the comparatively high and, in some countries, increasing prevalence of use of those substances.[8–10] National surveys indicate that with reference to at least one occurrence of the behavior in the last 30 days, between 13% and 25% of youths report having smoked tobacco[1,11,12] and between 17% and 42% report having consumed alcohol.[1,12] However, cigarette smoking and consumption of alcohol are both greatly exceeded by the consumption of caffeine, which national surveys indicate is consumed by 75% of adolescents on a typical day.[13,14]

The high prevalence of caffeine consumption by adolescents reflects the current wide range of available caffeine products, which during recent years has expanded greatly beyond the traditional beverages of coffee and tea. The main new product additions include a diverse range of soft drinks to which caffeine is added and caffeine-containing "energy drinks." Moreover, advertising has increasingly been

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designed to appeal to young consumers. These innovations in the commercial exploitation of caffeine, especially with reference to the youth market, have led to expressions of concern regarding possible health implications and have elicited calls for increased research.[15–17]

Of the many psychosocial outcomes and processes found to be associated with adolescent use of noncaffeine substances, sleep has emerged as a possible important mediator of behavioral and emotional sequelae.[18,19] Altered sleep patterns and brain architecture often occur in conjunction with active substance use, and it is evident that many adolescents receive less sleep than is thought desirable. For example, the National Sleep Foundation[14] in the United States has estimated that as many as 80% of adolescents receive less than an optimal amount of sleep. Sleep processes have particular salience in the context of regular caffeine use. At dietary doses, caffeine has the potential to increase latency to sleep,[20] and it has been reported that many adolescents actively employ caffeine to forestall sleep during nighttime leisure activities, including use of electronic devices such as videos and computer games.[21] In addition, periods of abstinence, even as brief as several hours, reliably produce withdrawal effects including increased sleepiness.[22–24]

In this article, we present what we believe to be the first study to conduct a population-wide examination of adolescent substance use that also includes self-report data on caffeine consumption, daytime sleepiness, and anger. We hypothesized that the frequency of caffeine consumption in adolescents substantially exceeds the use of nicotine and alcohol. In addition, we hypothesized that after controlling for potential confounders, caffeine consumption is positively associated with measures of daytime sleepiness and anger. Using structural equation modeling (SEM), we further hypothesized that the association between caffeine consumption and anger is partly mediated by daytime sleepiness and substance use. Finally, taking account of recent speculation that negative affect may play a greater role in drug use for girls than for boys,[6,25] we tested for gender differences.

Methods

Sample

This study utilized population-wide cross-sectional data from the latest in the series of surveys, *Youth in Iceland*, which monitor trends in a wide range of demographic and health-related variables.[26] Conducted by the Icelandic Centre for Social Research and Analysis (ICSRA) in cooperation with the Icelandic Ministry of Education, Science, and Culture, the survey reported here took place during February 2009 among 9th and 10th graders in all secondary schools in the country. All aspects of data collection, including participant involvement based on passive parental consent, were conducted in accordance with Icelandic guidelines for the protection of research subjects.

Under ICSRA oversight, teachers at each school supervised questionnaire completion onsite. All students who attended school on the day that the survey was scheduled completed the questionnaires within their regular classrooms. Students were instructed not to write their name, social security number, or any other identifying information anywhere on the questionnaire booklet. They were instructed to complete the entire booklet, but to ask for help if they had any problems or any questions for clarification. Once students completed the questionnaires, they were asked to place their completed booklet in an envelope provided for that purpose and seal the envelope before returning it to the supervising teacher. The response rate was 83.5% of the total national population in the relevant age groups and yielded 7348 questionnaires (50.8% girls) containing useable data available for this analysis.

Measures

Approximately 90% of the estimated 320,000 inhabitants of Iceland are of Norse-Celtic decent, with 80% of the population belonging to the Lutheran State Church and no other religious institution having more than 3% of the population registered in its services.[27] 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.

Caffeine use. Respondents reported their daily caffeine consumption as the number of glasses or cups of coffee, tea, cola drinks, or energy drinks that contain caffeine (e.g., Red Bull or Magic). Response options were "never" through seven steps to "six glasses/cups or more." For clarification, it should be mentioned that decaffeinated coffee and tea are rare in Iceland, making it unlikely that respondents were referring to such alternatives when reporting coffee and tea consumption.

Social support. Two measured constructs were used for social support: the perceived parental support scale and the same scale about peer support.[28] These are five-item scales designed to capture the level of perceived social support in the adolescent environment. Questions were headed by the sentence "How easy or hard is it for you to get from your parents/peers": (1) caring and warmth, (2) discussions about personal affairs, (3) advice about your studies, (4) advice about other issues, and (5) general assistance with things. Response categories were coded on a four-point scale with "very difficult," "rather difficult," "rather easy," and "very easy."

Licit substance use. Respondents were asked six questions about their use of cigarettes and alcohol: "How often in your lifetime have you" (1) smoked cigarettes, (2) had a drink of alcohol of any sort, and (3) got drunk; and the same three questions were asked in relation to usage during the last 30 days. Response options for all items apart from the question on smoking during last 30 days were "never" through a total of seven steps to "40 times or more." For the question on smoking during the last 30 days, the response items were "nothing," "less than 1 cigarette per week," "less than 1 cigarette per day," 1–5 cigarettes per day," "6–10 cigarettes per day," "11–20 cigarettes per day" and "more than 20 cigarettes per day."

Sleepiness. The Epworth Sleepiness Scale, modified and validated for use with children and adolescents,[29] was used to assess daytime sleepiness. The scale consists of eight items with the question: "How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired?": when sitting and reading, watching TV, sitting inactive in a public place and following something (e.g., watching a movie or in a meeting), when you are a passenger in a car for an hour or more without stopping, when lying

down to rest in the afternoon, when sitting and talking to someone, when sitting and relaxing after a meal, and when sitting in a car that has been stopped for a few minutes because of traffic. Response options were "very unlikely that I will doze off or fall asleep," "rather unlikely…," "rather likely…," and "very likely. …"

Anger. This five-item scale was designed to measure severity of anger.[30] Questions were headed with the sentence "During the past week how often did the following statements apply to you": "I was easily annoyed and irritated," "I experienced outbursts of anger that I could not control," "I wanted to break or damage things," "I got into a row," and "I yelled at somebody or threw things." Answers ranged from 0 = "never," 1 = "seldom," 2 = "sometimes" to 3 = "often."

Control variables. Parental education and the relative financial status of the family served as surrogate measures for socioeconomic status and were obtained by asking respondents separate questions about their fathers' and mothers' educational attainment and about their family's financial position relative to other families. Response options for the former question were "finished elementary school or less," "started but did not finish secondary school," "finished secondary school," "started university but did not finish," and "has a university degree." There were seven response categories for the latter question: "much better" than others, "considerably better," "somewhat better," "similar," "somewhat worse," "considerably worse," and "much worse." In addition, family structure was dichotomously measured as "lives with both parents" (70%) and "other arrangements."

Measurement model and data analysis

After examining the distributional properties for all variables, we conducted SEM using AMOS 17.0.[31,32] SEM allowed us to explicitly model direct and indirect effects using measured and latent variables.[33] We specified seven latent constructs in the analysis: parental education, parental support, peer support, caffeine consumption, licit substance use (nicotine and alcohol), sleepiness, and anger; and two directly observed variables: family structure and family financial status. The specification included the number of factors, the number of indicators for each factor, and whether the measurement errors were allowed to correlate or not. Confirmatory factor analysis was used from the beginning in the construction of all latent variables and was also used to test the fit of the hypothesized factor structure to the covariance matrix of the observed variables.

The SEM we tested may be expressed as the following equation: $\eta = \beta\eta + \Gamma\xi + \zeta$, where β is the matrix of regression weights interrelating the endogenous (η) variable of anger and the mediating variables of licit substance use and sleepiness. Γ is the matrix of regression weights relating the exogenous (ξ) variables, family structure, family financial status, and parental education, to the endogenous (η) variables and ζ is a vector of error terms. Hu and Bentler's[34] cutoff criteria for adequate-fit indices were adopted, with a comparative fit index (CFI) of 0.950 and above and the root mean square error of approximation (RMSEA) of below 0.050 indicating a good fit to the data. The data were then modeled with a multigroup approach separately for boys and girls. A relationship between two variables is generally considered to be mediated if it exists only when a third variable is included in the putative causal pathway.[35] Accordingly, the effects of parental and peer support and caffeine use on anger were estimated in the models and how their influences are potentially mediated through sleepiness and licit substance use. By the use of modification indices when forming the measurement model, we identified a substantial correlation between the residuals (error terms) for some of the latent structure indicators. This is not surprising when using multiple-item measures and is particularly evident in the "licit substance use" construct because the items are highly related to one another. Such correlations between the residuals of latent constructs are accounted for in the overall model fit statistics.[36] Between 0.9% and 2.4% of responses on each of the linear indicators were replaced with the respective mean score because of missing values.

Results

The prevalence of caffeine consumption on a typical day was 82.6% for boys and 70.4% for girls (76.3% for the combined sample). Regarding sleepiness, 80.7% of boys and 85.9% of girls responded with a "very likely" or "rather likely" on one or more of the eight sleepiness items (83.4% for the combined sample). A positive response to any of the substance use items was reported by 60% of boys and 58.2% of the girls (59.1% combined). Gender-divided descriptive statistics are presented for all study variables in Table 1. As shown, girls reported more parental and peer support on average than boys, with the difference being particularly marked for peer support. Boys reported more caffeine use on average than girls, with the difference being particularly marked for consumption of cola and energy drinks. Girls reported significantly more sleepiness overall than boys. However, with reference to the five specific settings included in the scale, girls reported more sleepiness for two and boys also reported more sleepiness for two (there being no difference for the fifth setting). There were no gender differences on the measures of "licit substance" use (i.e., cigarette smoking and alcohol consumption). Finally, girls reported more anger symptoms on average than boys, with the observed difference being mostly due to girls scoring higher for the question concerning being "easily annoyed or irritated." Boys, however, scored significantly higher for the item concerning "wanted to break things."

The SEM model split by gender had a CFI value of 0.958 and an RMSEA measure for a lack of fit of 0.024, indicating that the model fits the data very well. Table 2 summarizes the results of the SEM analyses for the gender-based models, which included separate analyses of the factor loadings and associated residual terms (errors) for each latent construct (data not shown). Figure 1 shows the standardized beta (β) coefficients for the relationships between key latent measures in the study, while simultaneously controlling for family structure, parent education, and family financial status. The variance explained ratio is also presented for the main outcome variables of sleepiness, licit substance use, and anger.

Parental support was moderately and negatively related to sleepiness for both boys ($\beta = -0.16$) and girls ($\beta = -0.15$). Similarly, parental support was negatively related to licit substance use for boys ($\beta = -0.16$) and girls ($\beta = -0.20$). AMOS was used to compute a table of critical ratios of differences

Table 1. Descriptive Statistics for All Study Variables Among Boys and Girls ($N=7348$)

	n			*Mean*		*SD*		
	Boys	*Girls*	*Score range*	*Boys*	*Girls*	*Boys*	*Girls*	*Mean difference*
Family structure	3615	3733	0–1	0.30	0.30	0.46	0.46	0.01
Family financial status	3615	3733	1–7	3.38	3.65	1.10	1.00	−0.26[a]
Mother education	3615	3733	1–6	4.26	4.01	1.56	1.60	0.25[a]
Father education	3615	3733	1–6	4.14	4.08	1.56	1.57	0.05
Parental education (scaled)	3615	3733	0–10	6.40	6.10	2.69	2.70	0.30[a]
Parental support								
Caring and warmth	3615	3733	1–4	3.60	3.72	0.66	0.57	−0.11[a]
Discussions about personal affairs	3615	3733	1–4	3.32	3.36	0.83	0.84	−0.04[b]
Advice about the studies	3615	3733	1–4	3.52	3.50	0.76	0.80	0.02
Advice about other issues	3615	3733	1–4	3.48	3.51	0.74	0.74	−0.02
Assistance with other things	3615	3733	1–4	3.45	3.53	0.73	0.71	−0.07[a]
Parental support (scaled)	3615	3733	0–15	12.37	12.61	3.05	3.04	−0.23[a]
Peer support								
Caring and warmth	3615	3733	1–4	2.92	3.57	0.84	0.63	−0.65[a]
Discussions about personal affairs	3615	3733	1–4	2.98	3.59	0.89	0.69	−0.60[a]
Advice about the studies	3615	3733	1–4	2.79	3.18	0.92	0.82	−0.39[a]
Advice about other issues	3615	3733	1–4	3.03	3.37	0.83	0.73	−0.34[a]
Assistance with other things	3615	3733	1–4	3.14	3.45	0.79	0.70	−0.32[a]
Peer support (scaled)	3615	3733	0–15	9.86	12.16	3.49	2.92	−2.30[a]
Caffeine								
Coffee	3615	3733	1–7	1.19	1.09	0.72	0.45	0.11[a]
Tea	3615	3733	1–7	1.22	1.22	0.66	0.57	−0.01
Cola drinks	3615	3733	1–7	2.56	1.98	1.55	1.20	0.58[a]
Energy drinks	3615	3733	1–7	1.76	1.39	1.14	0.75	0.37[a]
Caffeine (scaled)	3615	3733	0–24	2.73	1.67	2.91	2.02	1.05[a]
Daytime sleepiness								
Reading a book or magazine	3615	3733	1–4	2.16	2.21	1.07	1.01	−0.05[b]
Watching TV	3615	3733	1–4	2.24	2.40	0.97	0.93	−0.16[a]
Sitting inactive in public	3615	3733	1–4	2.06	1.90	0.97	0.89	0.16[a]
Passenger in a car for an hour+	3615	3733	1–4	2.26	2.48	1.00	0.96	−0.22[a]
Lay down to rest	3615	3733	1–4	2.64	2.85	1.01	0.94	−0.21[a]
Sitting and talking	3615	3733	1–4	1.37	1.26	0.71	0.58	0.11[a]
Sitting quietly after lunch	3615	3733	1–4	1.76	1.73	0.90	0.85	0.02
Stopped in a car for a few minutes	3615	3733	1–4	1.65	1.61	0.85	0.81	0.04[b]
Sleepiness (scaled)	3615	3733	0–24	8.13	8.44	5.13	4.57	−0.31[a]
Licit substance use								
Lifetime smoking	3615	3733	1–7	1.93	1.99	1.82	1.93	−0.06
Smoking during last 30 days	3615	3733	1–7	1.34	1.36	1.08	1.10	−0.02
Alcohol drink in lifetime	3615	3733	1–7	2.47	2.46	1.77	1.75	0.01
Alcohol drink in past 30 days	3615	3733	1–7	1.38	1.39	0.92	0.81	−0.01
Drunk in lifetime	3615	3733	1–7	1.64	1.71	1.38	1.38	−0.07[b]
Drunk in last 30 days	3615	3733	1–7	1.20	1.20	0.71	0.55	0.01
Licit substance use (scaled)	3615	3733	0–36	3.98	4.12	6.32	6.43	−0.15
Anger								
Easily annoyed or irritated	3615	3733	1–4	2.16	2.47	0.97	0.98	−0.30[a]
Outbursts of anger	3615	3733	1–4	1.43	1.52	0.77	0.86	−0.09[a]
Wanted to break things	3615	3733	1–4	1.74	1.61	0.98	0.94	0.12[a]
Had a row with someone	3615	3733	1–4	1.75	1.81	0.88	0.92	−0.06[b]
Yelled or threw things	3615	3733	1–4	1.33	1.35	0.73	0.74	−0.02
Anger (scaled)	3615	3733	0–15	3.41	3.76	3.37	3.52	−0.35[a]

[a] $p < 0.01$.
[b] $p < 0.05$.

among all pairs of free parameters. The critical ratio is the difference between the parameters divided by the estimated standard error of the difference.[31] Similar to the *t*-statistic, the critical ratio statistic can be compared with a table of the standard normal distribution to test whether all pairs of parameters listed in the table are equal. The critical ratio for the gender difference in the relationship between parental support and licit substance use was 2.08, indicating a significant difference at the 95% level. Parental support was also moderately and positively related to anger for boys ($\beta = -0.18$) and girls ($\beta = -0.21$). As with parental support and licit substance use, the gender difference between these parameters was statistically significant with a critical ratio of 2.03.

Caffeine was strongly related to sleepiness for boys ($\beta = 0.27$) and more strongly for girls ($\beta = 0.32$, critical ratio = 4.12, $p < 0.01$). Caffeine was very strongly and positively related to

Table 2. Structural Equation Modeling Summary, with Standardized and Unstandardized Regression Weights for the Model Split by Gender

	Standardized coefficients (β)B/G	*Unstandardized coefficients B/G*	*Standard error B/G*	*Critical ratio B/G*
Hypothesized relationships				
Parental support → Sleepiness	−16.[a]/−0.15[a]	−0.17/−0.14	0.022/0.019	−7.38/−7.08
Parental support → Licit substance use	−0.16[a]/−0.20[a]	−0.40/−0.54	0.049/0.049	−8.15/−11.02
Parental support → Anger	−0.18[a]/−0.21[a]	−0.19/−0.25	0.021/0.023	−8.74/−10.91
Peer support → Sleepiness	0.07[a]/0.03	0.07/0.03	0.022/0.025	3.01/1.27
Peer support → Licit substance use	0.10[a]/0.11[a]	0.25/0.40	0.049/0.065	5.04/6.23
Peer support → Anger	−0.02[a]/−0.11[a]	−0.02/−0.17	0.021/0.029	−1.11/−5.72
Caffeine use → Sleepiness	0.28[a]/0.32[a]	0.19/0.32	0.016/0.027	11.61/11.98
Caffeine use → Licit substance use	0.43[a]/.44[a]	0.72/1.32	0.040/0.075	18.21/17.46
Caffeine use → Anger	0.16[a]/0.16[a]	0.11/0.22	0.017/0.036	6.42/6.02
Sleepiness → Anger	0.19[a]/0.20[a]	0.19/0.27	0.021/0.028	8.99/9.68
Licit substance use → Anger	0.19[a]/0.22[a]	0.08/0.10	0.009/0.009	8.82/10.39
Control relationships				
Family structure → Parental support	−0.14[a]/−0.16[a]	−0.18/−0.21	0.022/0.021	−7.89/−9.61
Family structure → Peer support	−0.03/−0.05[b]	−0.04/−0.04	0.023/0.016	−1.86/−2.56
Family structure → Caffeine use	0.09[a]/0.19[a]	0.17/0.21	0.038/0.023	4.38/8.85
Family structure → Sleepiness	0.00/0.01	0.01/0.01	0.024/0.021	0.23/0.35
Family structure → Licit substance use	0.09[a]/0.10[a]	0.29/0.35	0.053/0.056	5.46/6.17
Family structure → Anger	−0.02/.00	−0.03/0.00	0.022/0.024	−1.16/0.11
Family financial status → Parental support	−0.16[a]/−0.16[a]	−0.09/−0.09	0.009/0.010	−9.35/−9.24
Family financial status → Peer support	−0.09[a]/−0.09[a]	−0.04/−0.04	0.009/0.008	−4.71/−5.04
Family financial status → Caffeine use	0.00/0.11[a]	0.00/0.06	0.016/0.011	0.03/−5.50
Family financial status → Sleepiness	0.06[a]/0.02	0.03/0.01	0.010/0.010	3.01/0.93
Family financial status → Licit substance use	0.07[a]/−0.02	0.09/−0.04	0.022/0.025	4.04/−1.42
Family financial status → Anger	0.01/−0.00	0.00/−0.00	0.009/0.011	0.34/−0.08
Parental education → Parental support	0.00/0.10[a]	0.00/−0.07	0.009/0.013	0.02/4.82
Parental education → Peer support	−0.05[b]/−0.01	−0.02/−0.01	0.011/0.010	−2.10/−0.52
Parental education → Caffeine use	−0.02/−0.02	−0.01/−0.01	0.015/0.014	−0.75/−0.87
Parental education → Sleepiness	−0.03/−0.05[b]	−0.01/−0.03	0.010/0.013	−1.36/−2.30
Parental education → Licit substance use	−0.05[b]/−0.11[a]	−0.05/−0.19	0.025/0.034	−2.19/−5.46
Parental education → Anger	−0.03/0.02	−0.01/0.01	0.009/0.014	−1.52/0.90

[a] $p < 0.01$ (two-tailed).
[b] $p < 0.05$ (two-tailed).

licit substance use for boys ($\beta = 0.43$) and girls ($\beta = 0.44$) and moderately related to anger for both genders ($\beta = 0.16$ for boys and girls). Peer support had a small and positive association with sleepiness for boys ($\beta = 0.07$), but this relationship was not significant for girls. Peer support was also positively modestly related to substance use for boys ($\beta = 0.10$) and girls ($\beta = 0.11$). On the other hand, peer support was not related to anger for boys, but was negatively modestly related to anger for girls ($\beta = -0.11$). Sleepiness was moderately related to anger for boys ($\beta = 0.19$) and girls ($\beta = 0.20$). Finally, licit substance use was moderately to strongly related to anger for boys ($\beta = 0.19$) and girls ($\beta = 0.22$).

To examine mediation effects, AMOS was used to produce tables with "total," "direct," and "indirect" effects, allowing estimation of the ratio of mediation between key variables. Notably, the standardized total effect between caffeine use and anger was 0.30, and the indirect effects were 0.13. This suggests that about 43% (13/30) of the total relationship between caffeine and anger was due to mediation by sleepiness and licit substance use. The same ratio for girls was 48% (0.16/0.33). The variance explained for the three key meditational and dependent variables is shown in Figure 1. For sleepiness, 11% of the variance was explained in the SEM model for boys and 14% for girls. Explained variance for licit substances was 24% for boys and 29% for girls, and explained variance for anger was 21% for boys and 30% for girls.

Discussion

Our findings indicate that caffeine has a significant and substantial presence in the lives of adolescents. The majority (76.3%) of this population cohort of 14–15-year-olds reported consuming caffeine daily. As hypothesized, caffeine consumption greatly exceeded the use of nicotine and alcohol. Of the four caffeine beverages surveyed, the general pattern of consumption was the same for boys and girls, with cola drinks being consumed most often, followed by energy drinks, tea, and coffee in that order. Boys reported overall higher levels of caffeine consumption than girls, whereas there were no differences between boys and girls in relation to use of nicotine and alcohol, with the exception that girls reported a slightly higher frequency of ever having been drunk.

There was a very strong tendency for those who reported increased use of caffeine to also report a history of use of nicotine and alcohol ($\beta = 0.43$ and 0.44 for boys and girls, respectively). Although the timing of initial use of these various substances is not revealed by our cross-sectional data, it

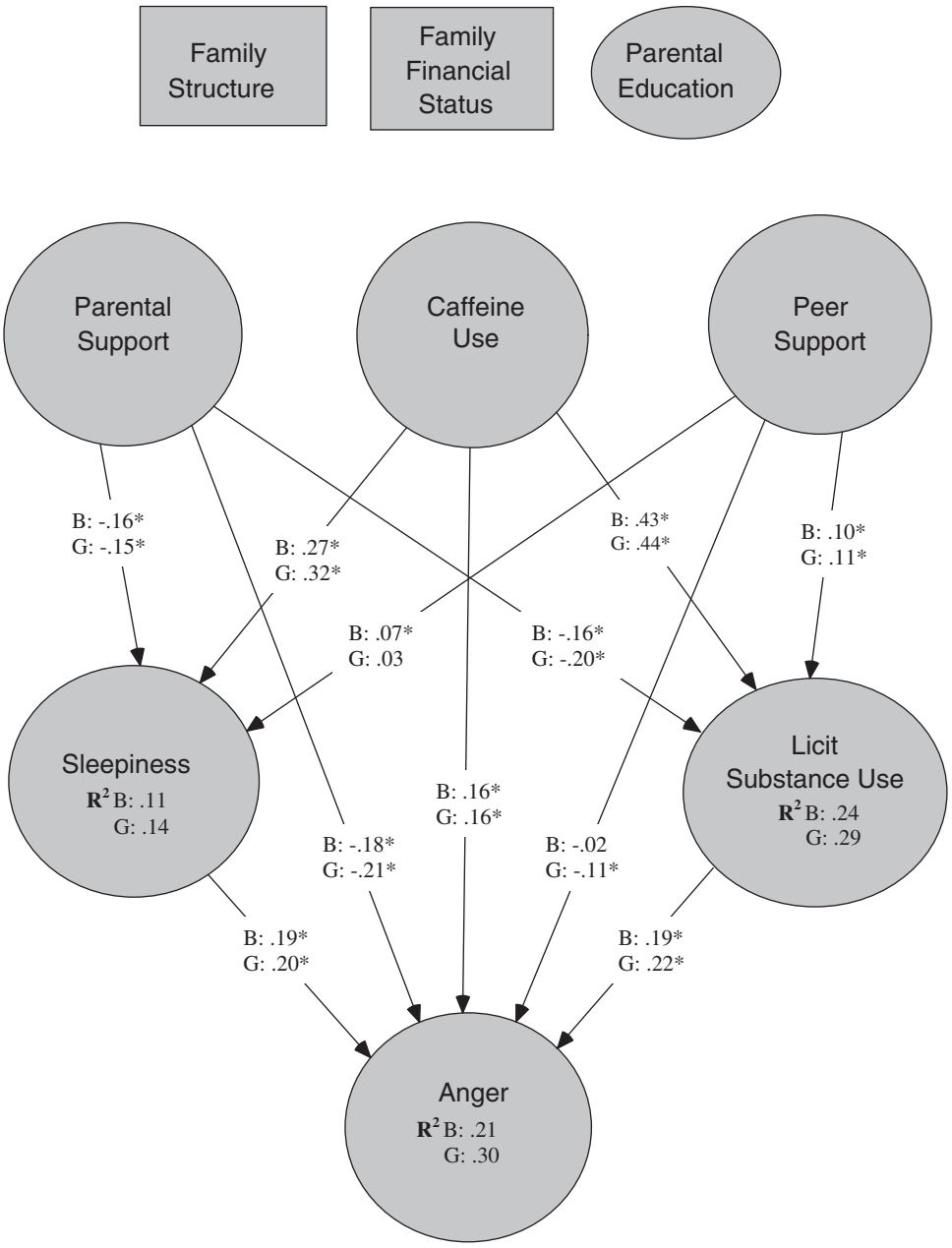

FIG. 1. SEM, structural equation modeling. Explained variance (R^2) and standardized pathways (with β values) between parental and peer support, caffeine, sleepiness, licit substance use, and anger. To avoid clutter, pathways from the control variables of family structure, family financial status, and parental education are not shown. Fit statistics for the SEM were $\chi^2 = 6068.37$ (df = 1166, $p < 0.000$), CFI = 0.958, and RMSEA = 0.024. *$p < 0.01$.

seems likely that caffeine consumption precedes smoking and alcohol use for most people. The pronounced strength of the relationship between caffeine consumption and use of nicotine and alcohol lends credence to the speculation by some authors that caffeinated soft drinks and energy drinks may serve as a "gateway" to use (i.e., in some way increase the likelihood of use) of other substances including nicotine and alcohol.[15,17]

There was also a strong tendency for caffeine consumption to predict sleepiness ($\beta = 0.28$ for boys and 0.32 for girls), a finding that has high biological plausibility. The actions of caffeine, both centrally and peripherally, are primarily due to competitive antagonism of adenosine,[37] and adenosine has a major role in sleep regulation.[37,38] Even at modest levels of caffeine use, there is adenosine receptor upregulation leading to increased functional sensitivity to endogenous adenosine, including the sleepiness that occurs during periods of caffeine abstinence.[23] Consequently, the observed positive association between adolescent caffeine consumption and daytime sleepiness in the present study is exactly what would be expected, especially if consumption tends to occur at evening time as has been reported to be the tendency for many adolescents.[21]

The SEM results indicate that caffeine consumption has important implications for understanding the contextual milieu to adolescent anger. Figure 1 shows that the direct relationship between caffeine and anger had a beta coefficient of 0.16 for both boys and girls. In addition, we found that almost half of the total relationship between caffeine and anger was mediated by licit substance use and sleepiness (43% for boys and 48% for girls). Although studies of adolescent substance use and sleep only rarely consider caffeine consumption, our

findings indicate the importance of including caffeine in studies of adolescent anger, and this finding complements a similar recent result concerning the role of caffeine consumption in adolescent academic performance.[13] That is, our findings add to the accumulating evidence regarding the importance of not overlooking caffeine consumption in studies of adolescent adjustment and development.

Although strengths of the study include large sample size, high participant-response rate, and strong associations between key variables, limitations should be noted. One limitation is the self-reported nature of key variables including caffeine consumption. Although previous research shows that self-reported caffeine use can provide reliable estimates of overall caffeine exposure,[39] it would be preferable if future studies included objective measurement based, for example, on high-performance liquid chromatographic analysis of saliva. An additional important general caveat relates to the need for caution regarding causal inferences in the context of cross-sectional data. For example, we cannot know for certain whether daytime sleepiness was exacerbated by caffeine withdrawal without knowing when caffeine was consumed. For the same reasons of lack of temporal information, we do not know the sequencing of events that underlies the observed relationships between caffeine consumption, licit substance use, and anger. However, the SEM approach adopted here does allow for a coherent interpretation of results that offers not only a good statistical fit of the data but also an interpretation that is consistent with the known psychopharmacology of caffeine (e.g., main biological mechanism of action and withdrawal effects).

Taking account of limitations, the present findings indicate the importance of further detailed study of caffeine consumption by adolescents. Prospective studies, in particular, are needed to clarify the developmental trajectory and consequential effects of adolescent caffeine consumption. Moreover, the high prevalence of reported caffeine use for our sample, as well as that observed by others,[14] suggests that caffeine is also probably being consumed by large numbers of preadolescent children. High prevalence of daily caffeine consumption and the strength of the observed associations between caffeine and other important biobehavioral and psychosocial variables provide strong justification for further detailed study of caffeine's potential effects for children and adolescents of all ages.

Author Disclosure Statement

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