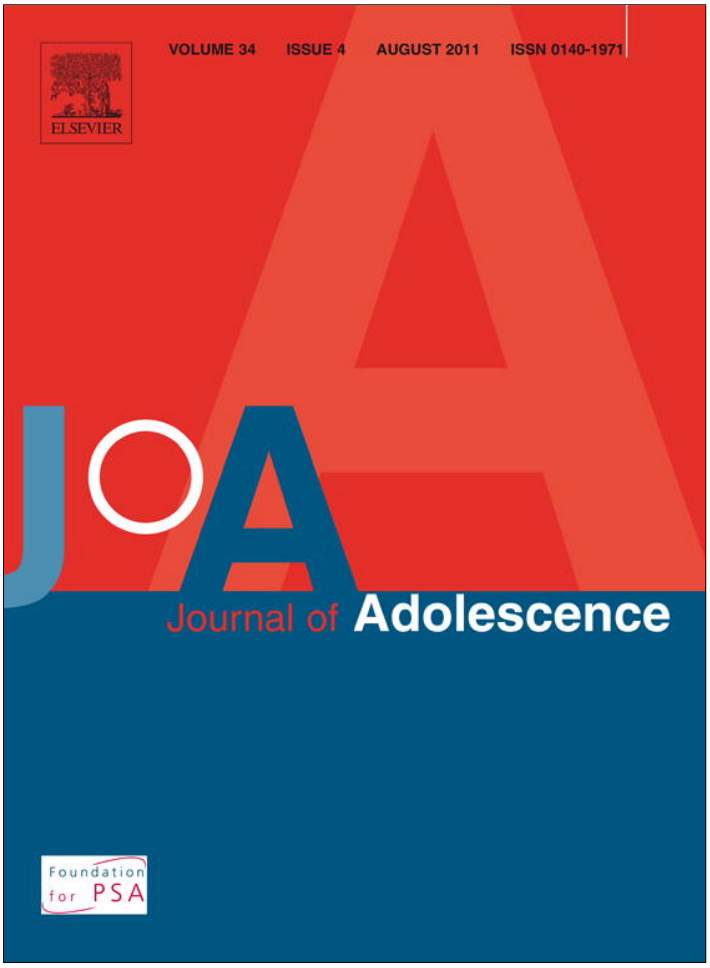
VOLUME 34 ISSUE 4 AUGUST 2011 ISSN 0140-1971
ELSEVIER
JoA
Journal of Adolescence
Foundation for PSA

Journal of Adolescence 34 (2011) 665–673

Contents lists available at ScienceDirect

Journal of Adolescence

journal homepage: www.elsevier.com/locate/jado

Adolescent substance use, sleep, and academic achievement: Evidence of harm due to caffeine

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Keywords:
Adolescence
Academic achievement
Substance use
Cigarette smoking
Alcohol
Caffeine
Caffeine withdrawal
Sleep
Daytime sleepiness

A B S T R A C T

Using academic achievement as the key outcome variable, 7377 Icelandic adolescents were surveyed for cigarette smoking, alcohol use, daytime sleepiness, caffeine use, and potential confounders. Structural equation modeling (SEM) was used to examine direct and indirect effects of measured and latent variables in two models: the first with caffeine excluded and the second with caffeine included. A substantial proportion of variance in academic achievement, which might otherwise have been attributed to the harmful effects of cigarette smoking and alcohol use, was found to be attributable to caffeine. Evidence was obtained that daytime sleepiness, which was found to be independently associated with usage of licit substances (nicotine and alcohol) and caffeine, may be an important mediator of the negative impact of those substances on academic achievement. Findings suggest the importance of including measurements of caffeine consumption in future studies of adolescent substance use.

It is well-accepted that adolescent substance use can have substantial negative effects on short- and long-term development and adjustment (e.g., Blum & Nelson-Mmari, 2004; Patel, Flisher, Hetrick, & McGorry, 2007). One early sign of potential harm is compromised academic achievement, which may be both a consequence of (e.g., Ellickson, Tucker, & Klein, 2001) and contributor to (e.g., Bryant, Schulenberg, O'Malley, Bachman, & Johnston, 2003) increased substance use. As a consequence of substance use, poor academic achievement appears not only to be a frequent immediate negative effect in its own right but also a stable predictor of other negative outcomes including poorer physical and mental health during adolescence and in adulthood (e.g., Mirowsky & Ross, 2003; Sigfusdottir, Kristjansson, & Allegrante, 2007). Of the range of licit and illicit substances used by adolescents, nicotine and alcohol have long been of particular concern (Bergen, Martin, Roeger, & Allison, 2005; Jeynes, 2002; Piko & Kovács, 2010).

Although interest in nicotine and alcohol is well justified, particularly considering their widespread use by adolescents, prevalence of use for both is greatly exceeded by the consumption of caffeine. Population surveys indicate that approximately 13% of American adolescents are likely to have smoked and 17% to have consumed alcohol in the *past month* (Substance Abuse and Mental Health Services Administration, 2002), whereas 75% of adolescents consume one or more caffeine beverages on a *typical day* (National Sleep Foundation, 2006). Although the ubiquity of caffeine possibly encourages beliefs that it is benign, its use cannot be assumed to be free of harm (e.g., James, 1997). When considering potential for harm, it is important to acknowledge that the range of available caffeine products has expanded greatly beyond the traditional beverages of coffee and tea. The main new additions include caffeine-containing "energy drinks" and a diversified variety of soft drinks to which

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doi:10.1016/j.adolescence.2010.09.006

caffeine is added. Product expansion has been accompanied by increased advertising designed to appeal to young consumers. It is not surprising, therefore, that there have been expressions of concern regarding the possible health implications of caffeine for young people and that such concerns have been accompanied by calls for increased research (e.g., Reissig, Strain, & Griffiths, 2009; Savoca et al., 2005; Temple, 2009).

Use of substances other than caffeine during adolescence has been associated with a wide array of behavioural and sociocultural outcomes and processes, with sleep emerging as a possible important mediator of behavioural sequelae (e.g., Mathers, Toumbourou, Catalano, Williams, & Patton, 2006; Pasch, Laska, Lytle, & Moe, 2010). Changed sleep patterns and architecture often occur in conjunction with active substance use. Additionally, substance use and changed sleep patterns, independently and combined, may negatively affect academic performance (e.g., Gromov & Gromov, 2009). Certainly, many adolescents receive less sleep than is thought desirable. For example, the United States National Sleep Foundation (2006) 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 (Landolt, 2008), 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 (Calamaro, Mason, & Ratcliffe, 2009). In addition, sleepiness is a confirmed effect of caffeine withdrawal even after periods of abstinence as brief as several hours (e.g., Juliano & Griffiths, 2004). Because children and adolescents tend to have less regular patterns of caffeine consumption than adults (James, 1991), they may be at increased risk of experiencing withdrawal-induced daytime sleepiness (Heatherley, Hancock, & Rogers, 2006; Pollak & Bright, 2003).

To our knowledge, this is the first population study of adolescent substance use to also have examined caffeine use in relation to key outcomes, including daytime sleepiness and academic achievement. There are, however, previous reports of high prevalence of caffeine use among adolescents, and extensive evidence of adverse withdrawal effects in adult consumers (Juliano & Griffiths, 2004). Accordingly, the broad aim of the present study was to compare associations between nicotine, alcohol use, daytime sleepiness, and academic achievement with and without consideration of concurrent use of caffeine. We hypothesized that frequency of caffeine consumption in our sample of adolescents would substantially exceed use of nicotine and alcohol. In addition, we hypothesized that after controlling for potential confounders caffeine consumption would be (a) positively correlated with measures of daytime sleepiness and (b) inversely correlated with academic achievement.

Methods

Sample

The present study utilized population-wide cross-sectional data from the latest in the series *Youth in Iceland* surveys which monitor trends in a wide range of demographic and health-related variables (Sigfusdottir, Thorlindsson, Kristjansson, Roe, & Allegrante, 2009). Conducted by the Icelandic Centre for Social Research and Analysis (ICSRA) in collaboration 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 in compliance with Iceland law on the protection of human subjects and approved by the Icelandic Data Protection Authority.

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. No identifying information was obtained. The response rate was 83.5% of the total national population in the relevant age groups, and yielded 7377 questionnaires (50.8% girls) available for analysis.

Measures

An estimated 90% of the approximately 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 3.0% of the population registered in its services (Statistics Iceland, 2009). 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.

Academic achievement

Respondents were asked to report their average grades in the four core academic subjects of Icelandic, Mathematics, English, and Danish/Norwegian/Swedish (whichever one of these three languages was part of the individual respondent's syllabus), required of all students in the 9th and 10th grades in Iceland. The grade range in Iceland in these subjects is 0–10, with a score of less than 5 indicating a fail grade. Response options were 1 = "under 4", 2 = "about 4", 3 = "about 5", 4 = "about 6", 5 = "about 7", 6 = "about 8", 7 = "about 9", and 8 = "about 10".

Licit substance use

Respondents were asked to report how often in their lifetime they had smoked cigarettes or had a drink of alcohol of any kind. Response options were 1 = "never", 2 = "once or twice", 3 = "3–5 times", 4 = "6–9 times", 5 = "10–19 times", 6 = "20–39 times", and 7 = "40 times or more". Due to skew in the distribution, scores for cigarette smoking were log transformed yielding a distribution with skew and kurtosis within the usual criterion of ±1.0 (Gujarati, 2003).

Caffeine use

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 1 = "never", 2 = "one glass/cup", 3 = "two glasses/cups", 4 = "three glasses/cups", 5 = "four glasses/cups", 6 = "five glasses/cups", and 7 = "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.

Sleepiness

The Epworth Sleepiness Scale (ESS), modified and validated for use with children and adolescents (Chan et al., 2009), was used to assess daytime sleepiness. The scale consists of eight items with the stem: "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 due to traffic. Response options were 1 = "very unlikely…", 2 = "rather unlikely…", 3 = "rather likely…", and 4 = "very likely that I will doze off or fall asleep".

Control variables

Parental education served as a surrogate measure for socioeconomic status, and 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". Family structure was dichotomously measured as "lives with both parents" (70%) and "other arrangements".

Measurement model and data analysis

After examining the zero-order correlation-matrix for all variables, we conducted structural equation modeling (SEM) using AMOS 5.0 (Arbuckle & Wothke, 1999; Maruyama, 1998). SEM allowed us to explicitly model direct and indirect effects using measured and latent variables (Bolle, 1989). We specified five latent constructs in the analysis: parental education, cigarette smoking and alcohol use (labeled "licit substance use"), sleepiness, caffeine use, and academic achievement, along with the two observed variables of gender and family structure. 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.

Table 1
Factor loadings from the two measurement models, with caffeine consumption excluded and included, respectively.

Indicator	Caffeine excluded	Caffeine included
Licit substance use:		
Smoking	.85	.85
Alcohol use	.80	.80
Caffeine consumption:		
Coffee	–	.38
Tea	–	.22
Cola drinks	–	.65
Energy drinks	–	.72
Sleepiness:		
Reading	.63	.63
Watching TV	.62	.62
Inactive in a public place	.69	.69
Passenger in a car	.57	.56
Lying down and resting	.58	.57
Talking to someone	.41	.41
Relaxing after a meal	.59	.59
In a stopped car	.51	.51
Academic achievement:		
Icelandic	.85	.84
Mathematics	.72	.72
English	.57	.57
Danish	.69	.69

Table 2
Fit statistics for the measurement and structural models, with caffeine consumption excluded and included, respectively.

Model	χ^2	*df*	*p*	CFI	RMSEA
Caffeine excluded:					
Measurement model	2070.74	122	.000	.944	.048
SEM	1568.71	116	.000	.958	.043
Caffeine included:					
Measurement model	2589.97	190	.000	.940	.043
SEM	2076.24	183	.000	.953	.039

Table 3
SEM (excluding caffeine) summary table showing standardized and unstandardized regression weights ($N = 7377$).

	Standardized coefficients (β)	Unstandardized coefficients	Standard error	Critical ratio
Hypothesized relationships:				
Licit substances → sleepiness	.34**	.01	.005	19.864
Licit substances → Acad. achievement	−.30**	−.20	.011	−17.548
Sleepiness → Acad. achievement	−.17**	−.34	.033	−10.526
Control relationships:				
Gender → licit substances	−.01	−.02	.037	−.451
Gender → sleepiness	.04	.03	.011	2.973
Gender → Acad. achievement	.16**	.28	.022	12.633
Family structure → licit substances	.21**	.66	.042	15.782
Family structure → Sleepiness	.01	.01	.012	.624
Family structure → Acad. achievement	−.09**	−.18	.024	−7.340
Parental educ. → licit substances	−.12**	−.16	.025	−6.497
Parental educ. → sleepiness	−.02	−.01	.007	−1.079
Parental educ. → Acad. achievement	.01	.01	.013	.564

*$p < .05$ (2-tailed), **$p < .01$ (2-tailed).

The SEM we tested may be expressed as the equation $\eta = \beta\eta + \Gamma\xi + \zeta$, where β is the matrix of regression weights interrelating the endogenous (η) variable of academic achievement, and the mediating variables of licit substance use, sleepiness, and caffeine use. Γ is the matrix of regression weights relating the exogenous (ξ) variables, gender, parental education, and family structure, to the endogenous (η) variables and ζ is a vector of error terms. Ho and Bentler's (1999) cut-off criteria for adequate-fit indices were adopted, with a comparative fit index (CFI) of .950 and above and the root mean square error of approximation (RMSEA) of below .050 indicating a good fit to the data. The data were then modeled in two ways: All variables except caffeine were included; then, all variables plus caffeine. A relationship between two variables is generally considered to be mediated if it exists (or is strengthened) when a third variable is included in the putative causal pathway (Baron & Kenny, 1986). Accordingly, the mediating effects of sleepiness on academic achievement were estimated in the first model (caffeine excluded) and the mediating effects of licit substance use and sleepiness in the second model (caffeine included), respectively.

Table 4
SEM (including caffeine) summary table showing standardized and unstandardized regression weights ($N = 7377$).

	Standardized coefficients (β)	Unstandardized coefficients	Standard error	Critical ratio
Hypothesized relationships:				
Caffeine use → licit substances	.44**	2.89	.153	18.911
Caffeine use → sleepiness	.17**	−.36	.042	8.552
Caffeine use → Acad. achievement	−.28**	−1.09	.087	−15.518
Licit substances → sleepiness	.26**	.08	.006	13.623
Licit substances → Acad. achievement	−.19**	−.12	.011	−10.888
Sleepiness → Acad. achievement	−.12**	−.26	.032	−8.098
Control relationships:				
Gender → caffeine use	−.27**	−.12	.008	−16.066
Gender → licit substances	.11**	.33	.39	8.581
Gender → sleepiness	.08**	.08	.012	6.183
Gender → Acad. achievement	.08**	.15	.023	6.219
Family structure → caffeine use	.13**	.06	.007	8.158
Family structure → licit substances	.16**	.49	.040	12.226
Family structure → sleepiness	.00	.02	.012	.187
Family structure → Acad. achievement	−.09**	−.16	.024	6.812
Parental educ. → caffeine use	−.02	.00	.004	−.847
Parental educ. → licit substances	−.12**	−.15	.024	−6.276
Parental educ. → sleepiness	−.02	−.01	.007	−1.397
Parental educ. → Acad. achievement	.02	.02	.012	1.271

*$p < .05$ (2-tailed), **$p < .01$ (2-tailed).

Results

For licit substances, 27.7% of respondents reported having smoked and 56.1% reported having consumed alcohol at least once in their lives, with 58.0% reporting having smoked or used alcohol at least once. By comparison, 75.8% reported consuming caffeine daily. Cola drinks were the main source (with 66.2% of respondents reporting daily consumption), followed by energy drinks (38.0%), tea (16.2%), and coffee (8.2%). Regarding sleepiness, 83.2% reported that they were "rather likely" and 40.1% that they were "very likely" to doze off or fall asleep in at least one of the eight situations described in the sleepiness scale.

Table 1 shows the factor loadings for the two measurement models, with and without the caffeine measure included. Apart from the coffee and tea indicators in the caffeine measure, all indicators loaded above .40 on the respective latent structures. Table 2 shows the fit statistics for the measurement and structural models with and without the caffeine measure included. The improvement between the measurement and structural models was tested against a chi-square distribution and yielded a highly significant improvement in the model fits in both instances (models without caffeine: $\chi^2(6) = 502.03$,

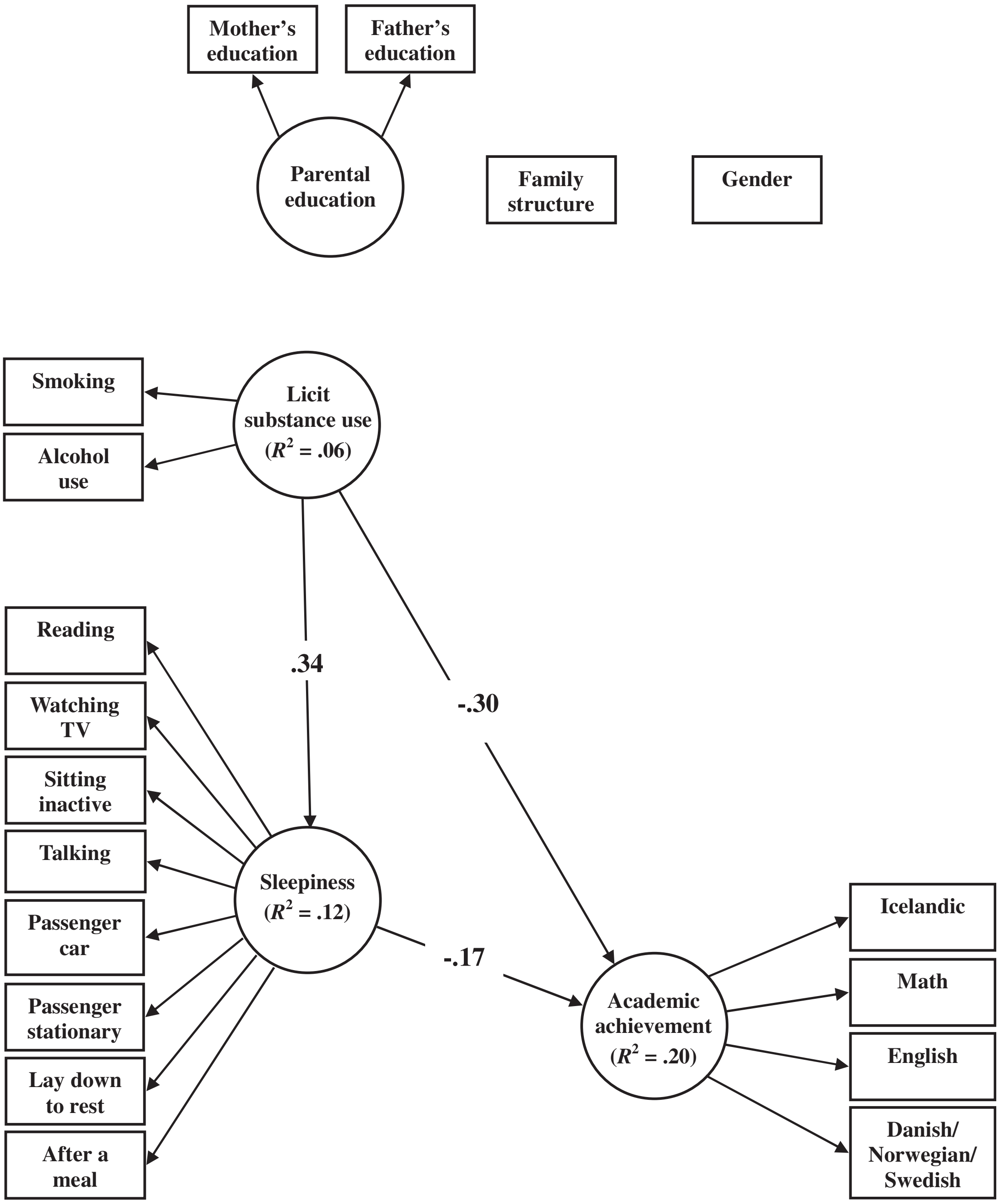

Fig. 1. Explained variance (R^2) and pathways (with β values) between licit substance use, sleepiness, and academic achievement. To avoid clutter, pathways from the control variables of gender, parental education, and family structure are not shown. Fit statistics for the SEM (Excluding Caffeine) were: $\chi^2 = 2355.20$ (df = 184, $p < .000$), CFI = .958, RMSEA = .043.

$p = .000$; models including caffeine: $\chi^2(7) = 513.73$, $p = .000$). When forming the measurement model, we identified a substantial correlation between the residuals (error terms) for some of the latent structure indicators which is accounted for by the structural models. First, the error terms for the "coffee" and "tea" indicators in the caffeine structure were allowed to be correlated and the same applied to the error terms for "English" and "Danish" in the academic achievement structure. Third, error terms were allowed to correlate for the following indicators in the sleepiness structure: "sitting in a car" and "talking to someone", "passenger in a car" and "being in a stopped car", "passenger in a car" and "laying down to rest", "laying down to rest" and "talking to someone", "talking to someone" and "relaxing after lunch", "talking to someone and "being in a stopped car", and "relaxing after lunch" and "being in a stopped car". Finally, the observed measure for gender and the error term for "Danish" were allowed to correlate.

Tables 3 and 4 summarize the results of the SEM analyses for the two models, which included separate analyses of the factor loadings and associated residual terms (errors) for each latent construct. Fig. 1 shows the relationship between licit substance use and academic achievement, and the degree to which this relationship was mediated by sleepiness (while simultaneously controlling for parent education, family structure, and gender, but excluding caffeine). Fig. 2 shows the role of caffeine by situating the caffeine variable in the path model before licit substance use.

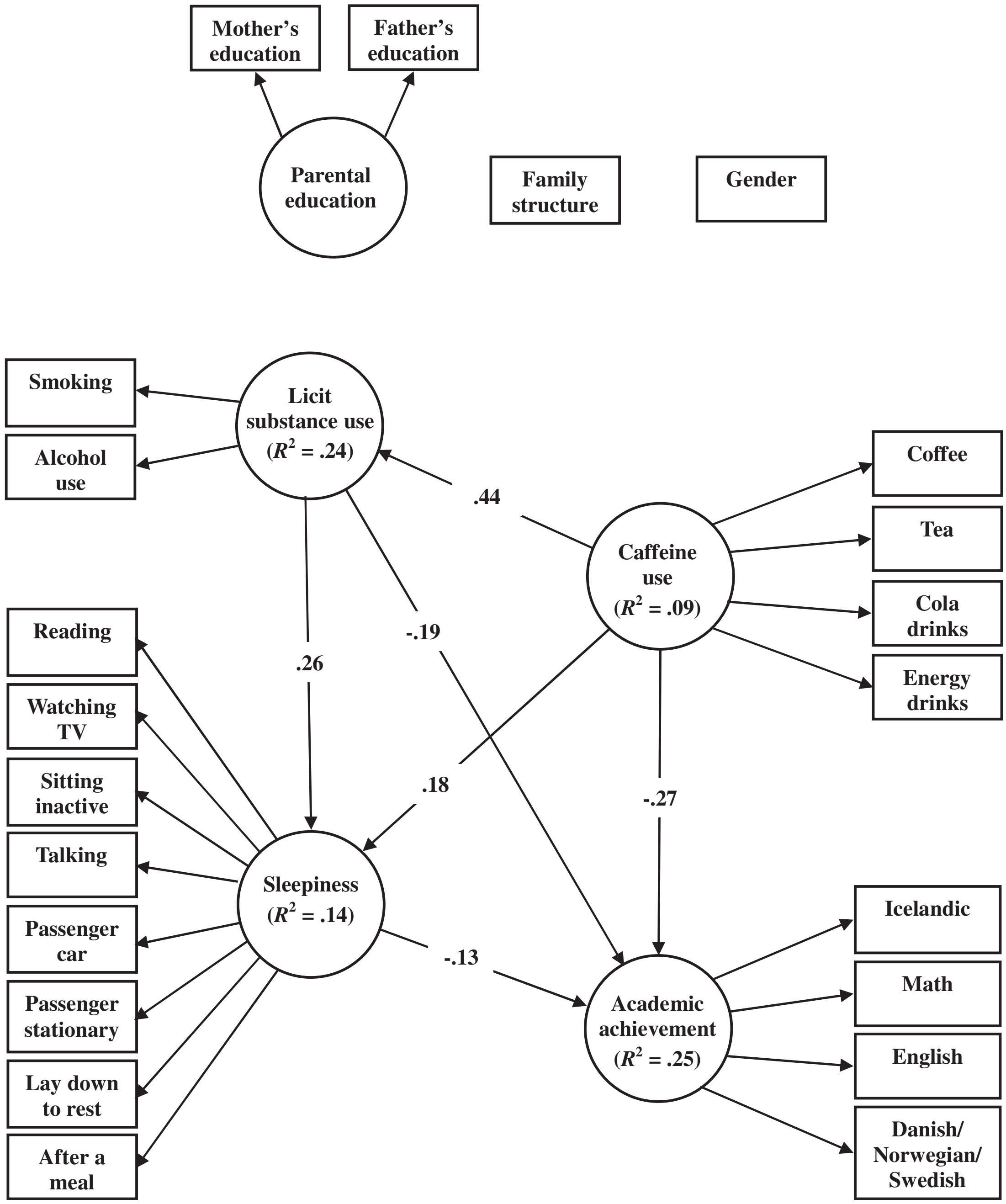

Fig. 2. Explained variance (R^2) and pathways (with β values) between caffeine use, licit substance use, sleepiness, and academic achievement. To avoid clutter, pathways from the control variables of gender, parental education, and family structure are not shown. Fit statistics for the SEM (Including Caffeine) were: $\chi^2 = 1794.77$ (df = 117, $p < .000$), CFI = .953, RMSEA = .039.

Table 3 and Fig. 1 show that with caffeine excluded licit substance use was strongly related both to sleepiness ($\beta = .34$) and (inversely) to academic achievement ($\beta = -.30$), and sleepiness was moderately related to academic achievement ($\beta = -.17$). The model yielded a β of $-.35$ for the standardized total effects of licit substance use on academic achievement (data not shown). These results indicate that 86% ($-.30/-.35$) of the relationship between licit substance use and academic achievement was due to direct effects, and that the remainder (14%) of the relationship between licit substance use and academic achievement was due to mediation through sleepiness. The model explained 6% of the variance in licit substance use, 12% for sleepiness, and 20% for academic achievement.

For the model that included caffeine use, Table 4 and Fig. 2 show that caffeine was very strongly related to licit substance use ($\beta = .44$), moderately related to sleepiness ($\beta = .18$), and strongly inversely related to academic achievement ($\beta = -.27$). A β of .30 was obtained for the standardized total effects of caffeine use on sleepiness, indicating that 60% (18/30) was due to direct effects of caffeine on sleepiness and the remainder of 40% was due to mediation through licit substance use. A β of $-.40$ was obtained for the standardized total effects of caffeine use on academic achievement, indicating that 68% ($-.27/-.40$) was due to direct effects of caffeine on academic achievement and the remainder of 32% was due to mediation through licit substance use and sleepiness. Licit substance use was also strongly related to sleepiness ($\beta = .26$), and academic achievement ($\beta = -.19$). A β of $-.23$ was obtained for the standardized total effects of licit substance use on academic achievement, indicating that 83% ($-.19/-.23$) of the relationship was due to direct effects and 17% was mediated indirectly through sleepiness. In turn, sleepiness was inversely moderately related to academic achievement ($\beta = -.13$). Finally, the model explained 24% of the variance for licit substance use, 14% for sleepiness, and 25% for academic achievement.

Discussion

As hypothesized, the frequency of reported caffeine use in our sample substantially exceeded reported use of nicotine and alcohol. In fact, the prevalence of daily usage of 75.8% found in the present study is essentially the same as the prevalence rate of 75% estimated by the National Sleep Foundation (2006) for American youth. In addition, as hypothesized, after controlling for parental education, family structure, and gender, caffeine consumption was positively correlated with measures of daytime sleepiness and was inversely correlated with academic achievement (see Fig. 2).

In relation to the broader aims of the study, results of both statistical models are consistent with previous findings of significant negative associations between adolescent licit substance use (i.e., smoking and alcohol) and academic achievement (Bryant et al., 2003; Ellickson et al., 2001). More specifically, the SEM results summarised in Fig. 1 suggest that the negative association between licit substance use and academic achievement was partially mediated by increased daytime sleepiness, which is consistent with recent findings and speculation (Calamaro et al., 2009; Gromov & Gromov, 2009; Mathers et al., 2006; Pasch et al., 2010). Particularly noteworthy, however, is the possible role of caffeine suggested by the results summarised in Fig. 2. Inclusion of caffeine use in the model not only increased explained variance in academic achievement (from 20% to 25%), but also shed new light on the possible role of caffeine in causal pathways involving substance use, sleepiness, and adolescent academic performance.

The strength of the relationship between use of licit substances and caffeine exceeded our expectations, as did the independent negative effect of caffeine on academic achievement. The strong tendency observed here for adolescents who use nicotine and alcohol to also consume caffeine is consistent with recent speculation that caffeine consumed in ubiquitously accessible forms, such as soft drinks and energy drinks, may serve as a “gateway” to use of other substances including nicotine and alcohol (Reissig et al., 2009; Temple, 2009). More specifically, while it has long been recognized that adolescent smoking and alcohol use are associated with poorer academic performance, the SEM results summarised in Figs. 1 and 2 indicate that the relationship may be partially, and even substantially, attributable to consumption of caffeine.

The finding that caffeine may have negative effects mediated by disruption to sleep processes has high biological plausibility. Pharmacological research has shown that the actions of caffeine at diverse sites, both centrally and peripherally, are primarily due to competitive antagonism of adenosine (e.g., Dunwiddie & Masino, 2001). Molecular similarities in the structure of caffeine and adenosine allow caffeine to occupy adenosine receptor sites, and it is noteworthy that adenosine has a major role in sleep regulation (e.g., James & Keane, 2007). Even at modest levels of caffeine use, there is adenosine receptor upregulation leading to increased functional sensitivity to endogenous adenosine and the associated behavioural, physiological, and subjective withdrawal effects that occur during caffeine abstinence (Juliano & Griffiths, 2004). Consequently, sleepiness during daytime hours, with consequential negative effects on academic achievement, is exactly what would be expected from intermittent use of caffeine, especially if consumption tends to occur at evening time.

The finding that caffeine may undermine academic achievement runs counter to popular beliefs that caffeine has performance-enhancing properties. However, extensive evidence from more than a decade of careful experimentation has shown that the putative performance-enhancing effects of caffeine, widely perceived to be net psychostimulant effects, are actually due to *reversal* of withdrawal effects (James, 1994, 1998; Yeomans, Ripley, Davies, Rusted, & Rogers, 2002; see James & Rogers, 2005 for a review). Sleepiness, lethargy, lack of attention, and decreased cognitive performance are common symptoms of caffeine withdrawal, and may appear as little as 6–8 h since caffeine was last ingested (Heatherley, Hayward, Seers, & Rogers, 2005). Improvements in performance following caffeine consumption are explained by reversal of such withdrawal effects (James & Rogers, 2005).

Notwithstanding the large sample size, high response rate, and the strength of the associations between key variables, limitations of the study should be noted. In particular, there is an important general caveat relating to the need for caution regarding causal inferences. The temporal relations between the substance-use variables that were examined are not revealed by the cross-sectional design employed here. For example, we cannot confirm whether regular use of caffeine typically preceded other licit substance use for those caffeine-consuming respondents who also reported use of nicotine and alcohol. Similarly, we cannot know whether daytime sleepiness was due to caffeine withdrawal without knowing when caffeine was consumed. Additionally, we cannot say whether variables other than caffeine that were not included in the present study (e.g., pre- and after-school activities or emotional states such as depression) also affected daytime sleepiness. These limitations indicate the need for more detailed investigations, including prospective studies, to clarify the developmental trajectory and consequential effects of adolescent caffeine consumption. Indeed, the high prevalence of reported caffeine use in our sample and others (National Sleep Foundation, 2006) suggests that caffeine is also probably being consumed by large numbers of pre-adolescent children, indicating the need for further research involving children and adolescents of all ages.

A further limitation of the present study is the self-report nature of the data. Confidentiality restrictions meant that we were unable to match self-reported academic achievement with school transcripts. Research by others, however, indicates that self-reported academic achievement can provide data of acceptable reliability and validity (e.g., Ross, 2006), especially when individual-subject reports are aggregated to form a composite score as was done in the present study (Cassady, 2001; Cole & Gonyea, 2010). Similarly, caffeine use was self-reported, and the unit of measurement ("glasses/cups") used is likely to have been approximate at best. Although previous research shows that self-reported caffeine use can provide reliable estimates of overall caffeine exposure (James et al., 1988), it would be preferable if future studies included objective measurement based, for example, on high performance liquid chromatographic (HPLC) analysis of saliva. Self-report methods were also used for measuring daytime sleepiness, using the ESS, modified for use with children and adolescents (Chan et al., 2009). This scale requires further study of its reliability and validity, especially given that shortcomings have been reported for the reproducibility of the adult version of the ESS (Nguyen et al., 2006).

In conclusion, the present study found that a substantial proportion of variance in academic achievement, which might otherwise have been attributed to the harmful effects of cigarette smoking and alcohol use, was found to be attributable to daily caffeine consumption. As such, present findings point to the need for further research involving study designs that can help to elucidate substance-specific effects. In addition, evidence was obtained that daytime sleepiness, which was found to be independently associated with usage of licit substances (nicotine and alcohol) and caffeine, may be an important mediator of the negative impact of those substances on academic achievement. Notwithstanding the need for caution when interpreting present findings, the high prevalence of daily caffeine use and the strength of the observed associations between caffeine and other key variables provide strong justification for further in-depth study of its potential effects on adolescent consumers.

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