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Sleep and Substance Use among US Adolescents, 1991–2014

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Abstract

Objectives—To examine associations between sleep and alcohol, amphetamine, cigarette, marijuana, and non-heroin narcotic use among US middle and high school students, trends in associations over time, and the comparative impact of select covariates on association strength.

Methods—Data from the 1991–2014 nationally representative Monitoring the Future study of 8th, 10th, and 12th grade US students were used to estimate standardized correlations between the frequency of getting at least 7 hours of sleep (7+ sleep) and substance use frequency while simultaneously regressing both outcomes on key covariate domains.

Results—As 7+ sleep frequency increased, substance use frequency significantly decreased and vice versa. Overall, association strength was inversely associated with grade. Associations were generally modest, varied across substances, and weakened over the historical period examined for 8th and 10th graders. Associations showed little variance by sex and racial/ethnic subgroups. Controlling for deviance, psychosocial, and general health covariates significantly attenuated association strength.

Conclusions—Among US secondary students, 7+ sleep/substance use associations were largely explained by individual deviance, psychosocial, and general health characteristics. Awareness and exploitation of these shared associations may be useful in improving substance use prevention and/or treatment efforts.

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Human Subjects Approval Statement

The University of Michigan Behavioral Sciences Institutional Review Board approved the study (HUM00063656).

Conflict of Interest Disclosure Statement

All authors of this article declare they have no conflicts of interest.

Keywords

sleep; substance use; adolescents; alcohol; tobacco; illicit drugs

INTRODUCTION

Research has established significant associations between adolescent sleep (especially sleep problems) and substance use (particularly alcohol use).^{1–5} Reported sleep/substance use associations are bidirectional: reduced sleep relates to higher substance use and vice versa.^{2,6,7} The risk for participating in any substance use and engaging in higher use frequency increases across adolescence.⁸ Physiological need for sleep also increases across adolescence.^{9,10} Yet, biological changes in circadian rhythm result in shifts to later preferred sleep times and frequently conflict with early school start times, resulting in chronic insufficient sleep and circadian misalignment.¹ Adolescent sleep/substance use associations are of particular concern given both the above-mentioned significant developmental changes in sleep and circadian rhythms and the particular susceptibility of the adolescent brain to deleterious effects of substance use.^{11,12}

Successful efforts to reduce and/or prevent adolescent substance use are based on accurate knowledge of risk factors—including concurrent behaviors—that are associated with increased substance use susceptibility. While research has established significant adolescent sleep/substance use associations, little is known about the extent to which sleep is concurrently associated with a range of specific substance use outcomes among the general adolescent population; if such associations vary by cohort or key sociodemographic subgroups; or if such associations are attenuated by controlling for known sleep and substance use risk covariates. Our purpose is to address these 3 gaps in the literature that may currently impede applied and theoretical advances.

Available Adolescent Sleep/Substance Use Research

Most adolescent sleep/substance use research has involved non-nationally-representative samples, either among the general population,^{4,7,13–16} or particular high-risk groups.^{2,17–19} To the authors' knowledge, only 4 nationally-representative adolescent sleep/substance use studies have been published.^{5,20–22} These studies have provided essential information on associations between various sleep dimensions (trouble sleeping, trouble staying asleep, insufficient sleep, hours of sleep) and use of a limited range of substances (alcohol, cigarettes, any illicit drugs, marijuana). The studies do not measure associations with substances such as amphetamines or narcotics, which are associated with sleep pharmacologically. In addition, none of the nationally-representative studies have examined whether sleep/substance use associations among the general adolescent population remain stable across cohorts. From 1991–2012, typical adolescent sleep duration declined;²³ substance use initially increased and then declined to varying degrees.⁸

Individual Characteristics Associated with Sleep and Substance Use

Adolescent substance use and sleep are each associated with a variety of social and psychological constructs.^{8,24–27} Based on adolescent substance use theory and adolescent

sleep research,^{26,27} the current analysis focused on specific sociodemographic, behavioral, and personality characteristics to be discussed below. While characteristics in these domains are known to be associated with sleep and substance use independently, much less is known about how they affect the way in which sleep and substance use co-vary. No studies have examined the comparative strength of these domains on sleep/substance use associations. Knowledge about which covariates have the strongest impact on adolescent sleep/substance use associations, and whether sleep and substance use are associated with each other above and beyond such potential “third variable” effects, would help inform and direct prevention efforts seeking to promote healthy sleep and prevent or reduce adolescent substance use.

Sociodemographic characteristics—Among adolescents and young adults, girls and racial/ethnic minorities are significantly less likely than boys and whites to report adequate sleep.^{23,27,28} Substance use differs by sex with patterns varying by substance type and historical period.⁸ Regarding racial/ethnic differences, use is generally higher among Hispanic, Native American, and white youth, as compared to African-American or Asian youth.^{8,29,30} A range of additional sociodemographic characteristics (such as socioeconomic status, household structure, region, and population density) are significantly associated with adolescent substance use and sleep.^{8,27} Limited research is available examining how sociodemographic covariates may moderate sleep/substance use associations. To our knowledge, only 2 non-nationally representative studies have done so: Pasch et al.¹⁴ found indications that sex may moderate adolescent sleep/alcohol use associations (the direction of moderation effect varied based on the sleep measure used); Troxel et al.¹⁶ found consistent associations between sleep and both alcohol and marijuana use across racial/ethnic subgroups.

Behavioral characteristics—Three domains of behavioral characteristics were investigated: general health behaviors, academic performance, and non-academic time use. *General health behaviors*: one reason an adolescent may both prioritize sleep and abstain from or limit their substance use may be that they strive to lead an overall healthy lifestyle. Research shows that adolescents who report healthy sleep patterns are also likely to report being physically active and/or having healthy diets,^{27,31} and that higher levels of general exercise (as opposed to sports participation) are associated with lower substance use.³² *Academic performance*: adolescents with strong priority on academic performance may make sure they meet a minimum sleep duration time in order to maintain high grades, but may also limit sleep in order to complete homework, prepare for tests, or participate in activities that will boost the likelihood of college admission.^{33,34} Higher academic performance has been shown to be consistently associated with lower substance use.^{35,36} *Non-academic time use*: engaging in activities such as work or socializing in the evenings results in less time for other activities including sleep. Also, engaging in such activities increases interactions with peers and decreases potential adult supervision. Both socializing with peers outside of the home,^{37,38} as well as working extensively during high school,^{39,40} have been shown to be associated with significantly higher adolescent substance use.

Personality characteristics—Two domains of personality characteristics were investigated: deviance and psychosocial constructs. *Deviance*. A range of behavioral

covariates that indicate rejection of societal rules/standards (such as truancy, aggression, and crime) have been strongly linked with adolescent substance use.^{41–44} Sleep also has been associated with deviance covariates, including truancy and aggression.^{14,18} *Psychosocial constructs*. Risk preference and self-esteem are widely recognized to relate to substance use. Risk preference is associated with higher substance use,⁴⁵ and low self-esteem is known to predict depression,⁴⁶ which is associated with increased risk for substance use.^{14,47} Conversely, inadequate sleep has been shown to be a prospective risk factor for later depression.^{14,22}

Present Study

This study contributes to available literature by using nationally-representative US middle and high school student samples from 1991–2014 to address 3 research questions (RQ):

RQ1. What is the extent of association between frequency of getting at least 7 hours of sleep a day and use of the following substances: cigarettes, alcohol, marijuana, amphetamines, and narcotics other than heroin?

RQ2. Does association strength vary between subgroups based on grade level (age), cohort, sex, or race/ethnicity?

RQ3. To what extent do associations hold after controlling for sociodemographics, general health, academic performance, non-academic time use, deviance, and psychosocial covariates?

METHODS

Sample

Data were obtained from the Monitoring the Future (MTF) study using annual nationally-representative cross-sectional 8th, 10th, and 12th grade student samples in the 48 contiguous states from 1991–2014 (detailed methodology available elsewhere).^{8,48} Self-completed, optically-scanned questionnaires were administered in classrooms by study personnel during a normal class period (only one grade was surveyed per school). From 1991–2014, an original or replacement school was obtained in 97% of sample units; student response rates averaged 90%, 87%, and 83% for 8th, 10th, and 12th grades, respectively. Absenteeism was the primary reason for nonresponse; less than 1% of students refused participation. The University of Michigan Behavioral Sciences Institutional Review Board approved the study.

Measures

All measures were self-reported by students except region and population density.

Sleep—Adolescent substance use has been associated with various sleep dimensions, including sleep problems, duration, and patterns/consistency.^{5,7,14,22} The MTF sleep measure used captures both consistency and duration of sleep: “How often do you get at least 7 hours of sleep?” (1=never, 2=seldom, 3=sometimes, 4=most days, 5=nearly every day, 6=every day). The measure has been used to document significant shifts in average nightly sleep among US adolescents.²³ The National Sleep Foundation (NSF) recommendations for sleep duration among healthy teenagers is between 8–10 hours.⁴⁹

While the 7+ hours cut-off should not be understood to indicate fully adequate sleep, the measured frequency of how often 7+ hours of sleep is obtained would capture the majority of those adolescents who do meet the recommended amount of sleep, and indicate the consistency of such behavior. Analyses (not shown) examining association linearity between 7+ hours of sleep and substance use indicated a linear association through “nearly every day”, but few differences between “nearly every day” and “every day”. The 7+ hours of sleep measure was recoded into a 5-point scale (0–4) by combining nearly every day and every day, and is hereafter referred to as “7+ sleep”.

Substance use frequency—Substances included both stimulants and depressants and were selected based on prior adolescent sleep/substance use research.^{1,2,7,17,19} Students reported past 30-day cigarette smoking as 1=not at all, 2=less than 1 cigarette per day, 3=1 to 5 cigarettes per day, 4=about 1/2 pack per day, 5=about 1 pack per day, 6=about 1 1/2 packs per day, 7=2 packs or more per day. For alcohol, amphetamines, marijuana, and narcotics other than heroin (hereafter referred to simply as “narcotics”), students reported past 12-month use frequency of each substance separately as 1=0 occasions, 2=1 to 2, 3=3 to 5, 4=6 to 9, 5=10 to 19, 6=20 to 39, and 7=40 or more occasions. (Examples of narcotics other than heroin are provided in the MTF questionnaire including OxyContin, codeine, etc. The MTF questionnaire has separate items for “heroin”, and “narcotics other than heroin”. Prevalence for heroin alone is very low—especially for 8th graders—and thus was not included in the current analyses.)

Covariates—Six covariate domains were selected based on prior research noted in the Introduction (see Table 1 for details on specific variables):

- Sociodemographics (6 measures): grade level; sex; race/ethnicity; 2-parent household; average parental education (a proxy for socioeconomic status); region; population density.
- General health (3 measures): frequency of eating breakfast; frequency of eating at least some green vegetables or fruit; frequency of exercising vigorously.
- Academic performance (2 measures): average academic grades; plans to graduate from a 4-year college.
- Non-academic time use (2 measures): average hours worked per week during the school year; number of evenings out for fun/recreation.
- Deviance (3 measures): truancy; interpersonal aggression scale; theft and property damage scale.
- Psychosocial constructs (2 measures): self-esteem scale; risk preference scale.

Data Analysis

All analyses accounted for school clustering and sample design in standard error estimates and were weighted to adjust for differential selection probability. Descriptive analyses were conducted using SAS v9.4. Descriptive comparisons of 7+ sleep and substance use by grade level were conducted using bivariate surveyreg models. Given the bidirectional nature of

adolescent sleep/substance use associations,^{2,7} a modeling approach not assuming directionality was used in Mplus 7.2 (specifying the MLR estimator and TYPE=COMPLEX to obtain estimates robust to non-normality and non-independence).⁵⁰ For RQ1, standardized correlations between 7+ sleep and use frequency of a single substance (with no covariates) were estimated for 1991–2014 combined. For the first part of RQ2, yearly standardized 7+ sleep/substance use correlations without covariates were estimated, and trends in obtained yearly correlations were modeled using Joinpoint 4.0.1.^{51,52} Based on observed cohort trends (see Results), further analyses were limited to 2010–2014. For the second part of RQ2, standardized 7+ sleep/substance use correlations for 2010–2014 combined (without covariates) were compared across grades, sexes, and racial/ethnic subgroups using multiple-group analysis. For RQ3, standardized 7+ sleep/substance use correlations from 2010–2014 were estimated in 3 stages. First, no covariates were included. Second, standardized correlations were estimated while simultaneously regressing both 7+ sleep and substance use on one covariate domain at a time. (Eg, for the deviance domain, both 7+ sleep and the specified substance use measure were simultaneously regressed on truancy, the interpersonal aggression scale, and the theft/property damage scale.) Finally, standardized correlations were estimated while regressing 7+ sleep and substance use on all covariate domains simultaneously (see Figure 1). Because analyses estimating changes over time in yearly bivariate 7+ sleep/substance use correlations utilized only 24 data points (one estimate per year), discussion includes findings with $p < .05$. Discussion of all other analyses (conducted at the student level) is limited to results with $p < .001$ due to the large sample size.

To reduce respondent burden but still obtain a wide variety of measures, MTF uses multiple questionnaire forms distributed randomly within classrooms, with some items not occurring on all forms. The analytical sample was limited to students responding to questionnaire forms including both 7+ sleep and substance use: 154,611 8th graders; 139,316 10th graders; and 85,960 12th graders. A total of 16.5% of respondents had missing data on 7+ sleep; missing data on substance use ranged from 2.6% to 6.3% of respondents. Missingness on covariates ranged from 0% to 20.1% (only 6 of 18 covariates had missingness rates of 15% or higher). Missing data were addressed using full-information maximum-likelihood (FIML) estimation in Mplus. By using FIML, Mplus uses all available data.^{53,54} Outcomes can include missing data and are modeled conditional on covariates; missing data on covariates are addressed by including covariates in the model (via modeling covariate means, thresholds or variances).⁵⁰

RESULTS

Descriptive Information

Descriptive statistics are shown in Table 1. Multi-grade comparisons of 7+ sleep and substance use (not shown) indicated the frequency of reporting at least 7 hours of sleep decreased significantly by grade ($p < .001$), while use frequency of all substances *increased* significantly by grade ($p < .001$). Significant non-linear decreases from 1991–2014 in 7+ sleep were seen for all grades (see Figure 2). As reported elsewhere,⁸ use of most substances

significantly increased during the early 1990s, and then declined to varying degrees (data not shown).

RQ1: Associations between 7+ Sleep and Substance Use

Table 2 reports bivariate standardized 7+ sleep/substance use correlations (r). All associations were negative: higher frequency of getting at least 7 hours of sleep was associated with lower substance use frequency. All associations were significant ($p < .001$) but relatively small.⁵⁵ For 8th graders, the strongest association was for sleep/alcohol ($r = -0.178$) followed by cigarettes and marijuana (both $r = -0.148$). For 10th and 12th graders, strongest associations were for sleep/cigarettes ($r = -0.138$ and -0.137 , respectively), followed by sleep/amphetamines for 10th graders ($r = -0.112$) and sleep/marijuana for 12th graders ($r = -0.083$). For all grades, sleep/narcotics had the weakest association. [Table 2 about here]

RQ2: Cohort and Subgroup Variation in Associations

Multi-group comparisons showed association strength significantly diminished ($p < .001$) as grade increased for all correlations except sleep/cigarettes. Figure 3 presents the estimated slopes of linear trends from 1991–2014 in grade-specific yearly bivariate standardized 7+ sleep/substance use correlations for alcohol, amphetamines, cigarettes, and marijuana. (No significant trends were observed for sleep/narcotics; data not shown.) Other than 12th grade sleep/marijuana, model fit was not significantly improved by moving beyond a single linear slope (indicating a linear decrease in association strength over time). For example, in 1991, 8th grade sleep/alcohol $r = -0.209$ (SE 0.016; $p < .001$). By 2014, the association had weakened to -0.154 (SE 0.025; $p < .001$). The estimated slope for this association from 1991–2014 was linear and positive (est. 0.0013; $p = .032$), reflecting gradual weakening of the 8th grade sleep/alcohol correlation over time. (Because all year-specific correlations were negative, positive slopes indicate associations weakening over time.) In addition to sleep/alcohol, 8th grade sleep/amphetamine and sleep/cigarette associations weakened significantly (8th grade sleep/marijuana showed no significant change). All associations for 10th graders weakened significantly from 1991–2014 excluding the association with narcotics. For 12th graders, sleep/cigarette associations weakened significantly and linearly between 1991–2014. No significant change in 12th grade sleep/marijuana associations was observed from 1991–2008, but associations significantly weakened from 2008–2012 (est. 0.017; $p = .043$) and then significantly strengthened from 2012–2014 (est. -0.043 ; $p = .020$). Given the significant changes in many associations over time, the sample for all following analyses was limited to the most recent 5 years (2010–2014) in order to focus on the current state of associations.

Multi-group comparisons examined bivariate 7+ sleep/substance use associations by sex and race/ethnicity. Only 2 associations showed significant sex differences, both indicating significantly stronger associations for 8th grade girls than boys. Standardized sleep/alcohol correlations were -0.209 (SE 0.013, $p < .001$) for 8th grade girls versus -0.125 (SE 0.015; $p < .001$) for boys. For sleep/amphetamines, $r = -0.122$ (SE 0.012, $p < .001$) for 8th grade girls and -0.067 (SE 0.012, $p < .001$) for boys. Significant racial/ethnic differences were found only for sleep/cigarettes (all 3 grades). Associations were significant and negative for White

and Hispanic students ($p < .001$), but no significance was observed among African American students (Table 3).

RQ3: Covariate Domain Effects on Associations

Standardized correlations obtained from analyses comparing covariate domain effects on adolescent 7+ sleep/substance use associations are shown in Table 4 (detailed final model results are available from the authors upon request).

All 2010–2014 bivariate associations were negative and significant except for 12th grade sleep/narcotics. The rank order of bivariate association strength by grade was similar to the ranking of associations obtained using 1991–2014 data, with the strongest 8th grade associations for sleep/alcohol ($r = -0.167$), and the strongest 10th and 12th grade associations for sleep/cigarettes ($r = -0.100$ and -0.120 , respectively). The second strongest association for all 3 grades was sleep/marijuana ($r = -0.138$, -0.088 and -0.055 , for 8th, 10th, and 12th grades, respectively). Sleep/narcotics continued to have the weakest associations.

In models including a single covariate domain, the largest reduction in association strength for all grades was observed after controlling for deviance covariates, reducing associations by an average of 55%, 48%, and 61% for 8th, 10th, and 12th grades, respectively. Controlling for psychosocial covariates resulted in the second-highest reduction in association strength for 8th and 10th graders (40% and 42% average reductions, respectively; 31% reduction for 12th graders). For 12th graders, the second-highest reduction was observed after controlling for general health covariates (58% average reduction; 31% and 37% average reductions for 8th and 10th graders, respectively). Academic performance covariates reduced associations by an average of 21%, 25%, and 24% for 8th, 10th, and 12th graders, respectively. Adjusting for sociodemographic characteristics somewhat reduced 8th grade associations (averaging an 8% decrease across substances) but slightly increased 10th and 12th grade associations (average increase of 3% for 10th and 8% for 12th graders). Non-academic time use covariates slightly increased associations for all grades (averaging a 2%, 11%, and 15% increase for 8th, 10th, and 12th grades, respectively).

Finally, covariates from all domains were included simultaneously to examine whether 7+ sleep/substance use associations held under the most stringent set of controls. Significant associations were found in only 4 final models: 8th grade sleep/alcohol and sleep/narcotics, and 10th grade sleep/amphetamines and sleep/cigarettes. These remaining significant associations were of very small size (the strongest was $r = -0.039$ for 8th grade sleep/alcohol).

DISCUSSION

Sleep quantity tends to decline and substance use tends to increase across adolescence,^{8,23,28} creating threats to adolescent health and well-being. This study examined concurrent associations between the frequency of reporting 7+ hours of sleep and substance use using nationally-representative samples of US adolescents including cohorts from 1991–2014.

RQ1 involved quantifying association strength between 7+ sleep and a range of substance use measures among this general risk adolescent population. Prior nationally-representative studies examining sleep and a limited number of substance use outcomes found significant and negative associations.^{4,13,15} The current study showed that the frequency of obtaining 7 or more hours of sleep was consistently and negatively associated with use frequency of a range of substances including stimulants and depressants. Associations were relatively small but varied considerably.

To some degree, 7+ sleep/substance use associations may be due to the pharmacological properties of various substances. While some adolescents report using substances specifically either to get to sleep or to stay awake,⁵⁶ substance use for any reason may pharmacologically affect sleep. In the current study, the associations between sleep/amphetamines (stimulants) and sleep/narcotics (depressants) were not strong and were in the same direction. Higher use frequency of both stimulants and depressants was associated with lower 7+ sleep frequency, arguing against a purely pharmacological explanation.

Alternative explanations of sleep/substance use associations posit that sleep (particularly sleep problems) may result in increased substance use by affecting emotional regulation and cognitive ability.⁶ For example, adolescents with sleep deficits may be more likely to act on impulse and participate in substance use when provided an opportunity. If so, one might expect sleep/substance use associations to be either somewhat equal across substances, or reflect general prevalence rates (with the highest associations found for substances that afford the highest opportunity for use). In the current study, 7+ sleep/substance use association strength for 8th graders did reflect general prevalence rates: the strongest recent (2010–2014) association was for sleep/alcohol and the lowest was for sleep/narcotics. Yet for 10th and 12th grade students, association strength did not reflect general prevalence rates, because the strongest recent (2010–2014) associations were found for cigarettes, followed by marijuana. The primary focus in adolescent sleep/substance research use has been on sleep/alcohol associations;¹ the literature has called for studies examining how sleep is associated with use across multiple substances.⁷ The current study indicates that efforts to expand sleep/substance use research to include a range of substances—particularly alcohol, cigarettes, and marijuana—are warranted.

RQ2 explored variation in 7+ sleep/substance use associations by grade level (age), cohort, sex, and race/ethnicity. Associations were strongest for the youngest adolescents. Eighth grade students reported the highest 7+ sleep frequency and lowest substance use frequency; sleep significantly decreased with age while substance use significantly increased. Concurrent associations between typical sleep frequency and substance use may weaken with age due to normative behavior changes. A stronger association among younger adolescents also could be hypothesized to reflect, at least to some degree, the higher likelihood of substance users dropping out of high school.⁵⁷ However, research indicates that differences in substance use prevalence by dropout status are strongest for cigarette use,⁵⁷ and the current research found that the sleep/cigarette associations showed the smallest shift in correlation strength by age. Clinicians, parents, and others working with adolescents may need to be alert to sleep and substance use associations particularly among younger adolescents.

To explore cohort differences, we examined variation in 7+ sleep/substance use associations across 2 decades. Other than sleep/cigarettes and sleep/marijuana, 12th grade associations did not change significantly over time. In contrast, most associations significantly weakened over time for 8th and 10th graders. Why should the strength of concurrent association between 7+ sleep and substance use be lower in recent years than in the early 1990s for younger adolescents? The current study found 7+ sleep decreased from 1991–2014 to a greater degree for 8th and 10th graders than for 12th graders. Published research shows that over the same time period, substance use for 8th, 10th, and 12th graders initially increased but then declined to varying degrees.⁸ Thus, especially for younger adolescents, it has become more normative in recent years to have lower 7+ sleep *and* lower substance use frequency, possibly lessening the observed association between higher 7+ sleep and lower substance use. Given less observed change over time in 12th grade 7+ sleep, and lower 12th grade 7+ sleep/substance use association strength to begin with, fewer changes over time were observed in association strength for these older adolescents.

We examined systematic variation in 7+ sleep/substance use associations by sex and race/ethnicity, building on known subgroup differences when examining sleep and substance use separately.^{8,23,28–30} Despite known subgroup differences in sleep and substance use, we found few differences in the degree to which the behaviors co-varied between sex and racial/ethnic subgroups. Stronger associations were found for 8th grade girls than boys for sleep/alcohol and sleep/amphetamines. These results were somewhat similar to those of Pasch et al.¹⁴ who found an association between weekend sleep delay and past-month alcohol use for girls but not boys (however, Pasch et al. also found only boys showed evidence of an association between weekday sleep and past-month alcohol use). Similar to work by Troxel et al.,¹⁶ the current study found no differences by race/ethnicity in associations between sleep and either alcohol or marijuana. We did find weaker associations among African Americans in all grades for sleep/cigarettes than whites and Hispanics. Cigarette smoking has historically been lowest among African American youth;^{8,58} weaker sleep/cigarette associations may be driven by lower cigarette use among this subgroup. These differences notwithstanding, the current study indicates that both sexes and all racial/ethnic groups appear to be at generally equal risk for associations between 7+ sleep and substance use: although sleep prevalence and substance use vary across sociodemographic groups, the associations between sleep and substance use vary much less.

RQ3 examined the extent to which 7+ sleep/substance use associations held after controlling for a range of covariates. After controlling for all covariates, little evidence remained for significant associations. Although the data were cross-sectional and thus preclude causal interpretation, these results indicate that reported frequency of sleeping 7+ hours per night may not be a strong independent risk marker for substance use among the general adolescent population. These results appear to be in contradiction to other recent research reporting that various sleep measures were associated with significantly increased alcohol and/or marijuana use among youth even after controlling for sociodemographic and mental health measures.¹⁶ However, there are important differences in how the associations were modeled. In previous research in this area, regression models with a single outcome (substance use) have been used. Sleep was entered as a predictor of substance use with other covariates. In

contrast, the current study measures the correlation between sleep and substance use while simultaneously regressing *both* sleep and substance use on the included covariates, resulting in a more accurate estimate of the remaining independent association between the 2 outcomes. These results do not diminish the importance of sleep for adolescent substance use. Our results suggest that, among the general adolescent population, the frequency of obtaining at least 7 hours of sleep and substance use are associated with each other mostly via shared associations with other behavioral, psychosocial, and lifestyle variables. Such shared associations can be used to possibly improve substance use prevention and/or treatment efforts. For example, if we know that covariates in certain domains are strongly associated with both sleep and substance use, then efforts to improve sleep may affect the specific covariates, which may then affect substance use. The current study indicates that covariate domains of deviance, psychosocial constructs, and general health have particularly strong impacts on adolescent 7+ sleep/substance use associations.

Deviance covariates (truancy, aggression, and theft/property damage) were associated most strongly with lower 7+ sleep and higher substance use frequency. While these findings are similar to prior research that found associations between adolescent sleep problems and substance use were significantly reduced after adjusting for delinquency and aggression,²⁰ they add to the literature by indicating that the impact on sleep/substance use associations of deviance covariates is stronger than that from other domains. Adolescents who spend more time in deviant activities may have less time for sleep. However, research indicates inadequate sleep leads to increased aggression among adolescent substance abusers, and aggression ideation is associated with higher substance use frequency.¹⁸ Sleep deprivation also has been found to be associated with low self-control, and low self-control has been linked with a range of behaviors including substance use and other non-violent and violent delinquent behaviors.⁵⁹

The psychosocial domain (self-esteem and risk preference covariates) was associated with the second largest decrease in 7+ sleep/substance use associations for 8th and 10th graders. These findings again are similar to prior research that found associations between adolescent sleep problems and substance use were significantly reduced after adjusting for anxiety/depression.²⁰ Changes occurring in adolescent sleep patterns—especially the mismatch between sleep-wake timing imposed by school schedules and changing circadian rhythms—have been linked with brain reward system disruptions associated with both increased risk-taking and sensation-seeking, as well as alcohol use disorders.³ Individuals preferring later sleep/wake schedules have been shown to have altered neural response to reward; neural response to reward anticipation is reduced while reactivity to win outcomes is increased.⁶⁰ Prospective studies have shown childhood sleep problems lead to poor adolescent response inhibition, which mediates observed childhood sleep/young adult drug association.¹⁹

The general health covariate domain was associated with the second largest decrease in sleep domain/substance use associations for 12th graders. Adolescents with healthy habits (indicated by fruit and vegetable consumption, eating breakfast, and exercising) also slept more and used substances less. Physical activity appears to reduce depression and anxiety,⁶¹ and longitudinal effects of sleep have been shown to affect later self-esteem and depressive symptoms,⁶² Promoting an overall healthy lifestyle among adolescents and emphasizing the

health-promoting effects of sleep are potential avenues of promoting sleep and reducing substance use.

These findings should be viewed within the context of study limitations. The data are cross-sectional and preclude causal interpretation. Sleep and substance use were self-reported. The MTF sleep measure did not clarify if the reported sleep was obtained in consecutive hours or at night. As noted previously, the National Sleep Foundation recommends that teenagers obtain 8–10 hours of sleep.⁴⁹ The MTF sleep measure used reflected the frequency of obtaining 7+ hours of sleep; adolescents reporting such sleep levels may be well-rested or may still have some level of sleep deprivation. Research involving additional measures of sleep may identify stronger and/or more nuanced sleep/substance use associations.

Acknowledging these limitations, the data presented here enable analyses to examine how a clear and stable measure of sleep has been associated with a range of adolescent substance use outcomes within a nationally-representative sample of middle and high school students using cohorts covering a 24-year time period.

Conclusions

This study used nationally-representative data to examine concurrent associations between one measure of adolescent sleep and substance use. Associations were consistently negative but modest in effect size, stronger for younger adolescents, and decreased significantly from 1991–2014. Associations were strongly related to individual deviance, psychosocial, and general health characteristics. Awareness and exploitation of these shared associations can be used to possibly improve substance use prevention and/or treatment efforts.

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Figure 1.
Full Multivariate Correlation Path Analysis Model

Figure 2. Trends in the Frequency of Getting at Least 7 Hours of Sleep among US Secondary Students, 1991–2014

Notes: Frequency of getting at least 7 hours of sleep measured as never (0), seldom (1), sometimes (2), most days (3), nearly every day/every day (4). Slope estimates for 8th grade: Slope 1 = -0.016 (SE 0.003; $p < .001$); joinpoint=1999; Slope 2 = -0.064 (–); joinpoint=2001; Slope 3 = 0.066 (–); joinpoint=2003; Slope 4 = -0.014 (SE 0.005, $p = .026$); joinpoint=2010; Slope 5 = 0.050 (–); joinpoint=2012; Slope 6 = -0.082 (SE 0.032, $p = .029$). Slope estimates for 10th grade: Slope 1 = -0.035 (SE 0.005, $p < .001$); joinpoint=1999; Slope 2 = 0.000 (SE 0.002, $p = .905$). Slope estimates for 12th grade: Slope 1 = -0.032 (SE 0.004, $p < .001$); joinpoint=2002; Slope 2 = 0.022 (SE 0.004, $p < .001$); joinpoint=2012; Slope 3 = -0.055 (SE 0.050, $p = .287$).

Figure 3. Trends in Standardized Bivariate Correlations between Frequency of Getting at Least 7 Hours of Sleep and Substance Use: US Secondary Students, 1991–2014

Notes: Each slope estimate based on modeling change in standardized correlations over 24 time points (1991–2014). Sleep/alcohol slopes: 8th grade 0.0013 (SE 0.0006, $p = .032$); 10th grade 0.0040 (SE 0.0005, $p < .001$); 12th grade 0.0013 (SE 0.0008, $p = .126$). Sleep/amphetamine slopes: 8th grade 0.0016 (SE 0.0006, $p = .021$); 10th grade 0.0017 (SE 0.0006, $p = .009$); 12th grade 0.0010 (SE 0.0008, $p = .187$). Sleep/cigarette slopes: 8th grade 0.0049 (SE 0.0006, $p < .001$); 10th grade 0.0046 (SE 0.0005, $p < .001$); 12th grade 0.0024 (SE 0.0006, $p < .001$). Sleep/marijuana slopes: 8th grade 0.0012 (SE 0.0006, $p = .067$); 10th grade 0.0022 (SE 0.0005, $p < .001$); 12th grade slope 1 (from 1991–2008): -0.0009 (SE 0.0006, $p = .135$); slope 2 (from 2008–2012): 0.0170 (SE 0.0078, $p = .043$); slope 3 (from 2012–2014): -0.0429 (SE 0.0167, $p = .020$).

Table 1

Descriptive Statistics: 1991–2014 Combined

	Range	Grade 8		Grade 10		Grade 12	
		Mean or %	(SE)	Mean or %	(SE)	Mean or %	(SE)
How often get at least 7 hours of sleep	0–4	3.22	(0.005)	2.92	(0.006)	2.58	(0.008)
Never	0, 1	3.4%	(0.069)	3.7%	(0.073)	5.1%	(0.112)
Seldom	0, 1	7.5%	(0.101)	11.9%	(0.132)	17.4%	(0.195)
Sometimes	0, 1	12.9%	(0.136)	18.7%	(0.152)	23.7%	(0.198)
Most days	0, 1	15.9%	(0.134)	20.0%	(0.138)	22.1%	(0.182)
Nearly every day/every day	0, 1	60.3%	(0.232)	45.8%	(0.243)	31.5%	(0.256)
Substance use							
Alcohol ^a (past 12 months)	1–7	1.86	(0.009)	2.58	(0.012)	3.15	(0.019)
Amphetamines ^a (past 12 months)	1–7	1.12	(0.002)	1.20	(0.004)	1.22	(0.005)
Cigarettes ^b (past 30 days)	1–7	1.23	(0.005)	1.38	(0.007)	1.51	(0.008)
Marijuana ^a (past 12 months)	1–7	1.33	(0.007)	1.83	(0.011)	2.11	(0.014)
Narcotics other than heroin ^a (past 12 months)	1–7	1.08	(0.002)	1.15	(0.003)	1.18	(0.005)
Sociodemographics							
Boys	0, 1	48.8%	(0.180)	49.1%	(0.260)	49.2%	(0.294)
Race/ethnicity							
White	0, 1	58.5%	(0.755)	65.5%	(0.736)	65.2%	(0.852)
African American	0, 1	14.2%	(0.582)	12.0%	(0.522)	12.0%	(0.541)
Hispanic	0, 1	13.6%	(0.564)	11.9%	(0.511)	12.6%	(0.640)
Other	0, 1	13.8%	(0.280)	10.5%	(0.270)	10.2%	(0.287)
Two-parent household	0, 1	74.1%	(0.338)	75.0%	(0.312)	68.5%	(0.370)
Average parental education ^c	1–6	3.97	(0.015)	3.94	(0.016)	3.89	(0.017)
Region							
Midwest	0, 1	24.2%	(0.615)	25.9%	(0.682)	24.8%	(0.732)
Northeast	0, 1	18.1%	(0.605)	19.9%	(0.598)	18.9%	(0.698)
West	0, 1	20.6%	(0.661)	20.9%	(0.726)	20.8%	(0.809)
South	0, 1	37.0%	(0.748)	33.4%	(0.760)	35.5%	(0.847)

	Range	Grade 8		Grade 10		Grade 12	
		Mean or %	(SE)	Mean or %	(SE)	Mean or %	(SE)
Metropolitan statistical area	0, 1	76.8%	(0.631)	76.8%	(0.665)	76.9%	(0.658)
General health: How often... ^d							
...eat breakfast	1–6	4.08	(0.010)	3.82	(0.011)	3.63	(0.012)
...eat at least some green vegetables or fruit	1–6	4.69	(0.008)	4.54	(0.008)	4.40	(0.009)
...exercise vigorously	1–6	4.43	(0.009)	4.23	(0.008)	3.82	(0.010)
Academic performance							
Average academic grades ^e	1–9	6.14	(0.018)	5.81	(0.019)	6.34	(0.017)
Will graduate from 4-year college	0, 1	61.9%	(0.303)	59.0%	(0.349)	58.0%	(0.414)
Non-academic time use							
Average hours worked per week during school year ^f	1–8	1.67	(0.007)	2.07	(0.013)	3.64	(0.021)
Evenings out for fun/recreation ^g	1–6	3.06	(0.009)	3.12	(0.009)	3.41	(0.010)
Deviance							
Truancy ^h	1.0–6.5	1.21	(0.003)	1.36	(0.006)	1.64	(0.009)
Interpersonal aggression ⁱ	1–5	1.38	(0.004)	1.30	(0.003)	1.27	(0.004)
Theft and property damage ^j	1–5	1.36	(0.003)	1.38	(0.003)	1.38	(0.004)
Psychosocial constructs							
Self-esteem ^k	1–5	3.97	(0.005)	3.97	(0.004)	4.02	(0.005)
Risk preference ^l	1–5	3.13	(0.007)	3.23	(0.006)	3.23	(0.008)

Notes: Ns (unweighted) = 8th grade 154,611; 10th grade 139,316; 12th grade 85,960.

^aMeasured as 0 occasions (1), 1 to 2 (2), 3 to 5 (3), 6 to 9 (4), 10 to 19 (5), 20 to 39 (6), 40 or more occasions (7).

^bMeasured as not at all (1), less than 1 cigarette per day (2), 1 to 5 cigarettes per day (3), about 1/2 pack per day (4), about 1 pack per day (5), about 1 1/2 packs per day (6), 2 packs or more per day (7).

^cCalculated as the mean of both parents using a scale ranging from 1=completed high school or less to 6=graduate or professional school after college (missing data on one parent allowed).

^dMeasured as never (1), seldom (2), sometimes (3), most days (4), nearly every day (5), every day (6).

^eMeasured on a continuous scale ranging from 1=D or below to 9=A.

^fMeasured as none (1), 5 or less (2), 6–10 (3), 11–15 (4), 16–20 (5), 21–25 (6), 26–30 (7), more than 30 (8).

^gMeasured as less than one (1), one (2), two (3) three (4), four or five (5), six or seven (6).

- h* Defined as the average of 2 past 4-week measures: (1) whole days of school missed due to skipping or cutting, and (2) frequency of attending school but skipping a class.
- i* Mean of the following 3 items: During the last 12 months, how often have you (a) gotten into a serious fight in school or at work? (b) taken part in a fight where a group of your friends were against another group? (c) hurt someone badly enough to need bandages or a doctor? (response options on a 1–5 scale of not at all, once, twice, 3 or 4 times, 5 or more times). Higher scores indicate higher interpersonal aggression. Scale reliability (α) by grade: .79 8th grade; .81 10th grade; .78 12th grade.
- j* Mean of 4 items: During the last 12 months, how often have you (a) taken something not belonging to you worth over \$50? (b) taken something not belonging to you worth over \$50? (c) gone into some house or building when you weren't supposed to be there? (d) damaged school property on purpose? (response options on a 1–5 scale of not at all, once, twice, 3 or 4 times, 5 or more times). Higher scores indicate higher involvement with theft and/or property damage. Scale reliability (α) by grade: .77 8th grade; .77 10th grade; .82 12th grade.
- k* Mean of 8 items: How much do you agree or disagree with each of the following statements? (a) I take a positive attitude toward myself. (b) I feel I am a person of worth, on an equal plane with others. (c) I am able to do things as well as most other people. (d) On the whole, I'm satisfied with myself. (e) I feel I do not have much to be proud of. (f) Sometimes I think that I am no good at all. (g) I feel that I can't do anything right. (h) I feel that my life is not very useful (response options were on a 1–5 scale of disagree, mostly disagree, neither, mostly agree, agree). Items indicating lack of self-esteem were reverse-coded; higher scores indicate higher self-esteem. Scale reliability (α) by grade: .84 8th grade; .86 10th grade; .88 12th grade.
- l* Mean of 2 items: How much do you agree or disagree with each of the following statements? (a) I get a real kick out of doing things that are a little dangerous. (b) I like to test myself every now and then by doing something a little risky (response options on a 1–5 scale of disagree, mostly disagree, neither, mostly agree, agree). Higher scores indicate higher risk preference. Scale reliability (α) by grade: .76 8th grade; .78 10th grade; .83 12th grade.

Standardized Bivariate Correlations between Frequency of Getting at Least 7 Hours of Sleep and Substance Use among US Secondary Students, 1991–2014

Table 2

	Grade 8			Grade 10			Grade 12		
	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>
<u>Correlation between sleep frequency and use frequency of:</u>									
Alcohol (past 12 months)	–0.178	(0.004)	<.001	–0.109	(0.004)	<.001	–0.080	(0.005)	<.001
Amphetamines (past 12 months)	–0.123	(0.004)	<.001	–0.112	(0.004)	<.001	–0.076	(0.005)	<.001
Cigarettes (past 30 days)	–0.148	(0.005)	<.001	–0.138	(0.004)	<.001	–0.137	(0.005)	<.001
Marijuana (past 12 months)	–0.148	(0.004)	<.001	–0.109	(0.004)	<.001	–0.083	(0.005)	<.001
Narcotics other than heroin (past 12 months)	–0.088	(0.004)	<.001	–0.085	(0.004)	<.001	–0.066	(0.005)	<.001

Notes: *N*s (unweighted) = 8th grade 154,611; 10th grade 139,316; 12th grade 85,960. Results of multi-group comparisons showed that correlations significantly diminished ($p < .001$) as grade increased for all sleep/substance use correlations except cigarette use, where the difference between 10th and 12th grades did not meet the $p < .001$ standard.

Racial/ethnic Differences in Standardized Bivariate Correlations between Frequency of Getting at Least 7 Hours of Sleep and Cigarette Use, 2010–2014

Table 3

	White		African American		Hispanic		Other	
	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)
8 th Grade	−0.126	(0.014)	<.001	−0.025	(0.031)	0.419	−0.137	(0.028)
10 th Grade	−0.132	(0.012)	<.001	−0.031	(0.029)	0.298	−0.034	(0.026)
12 th Grade	−0.160	(0.017)	<.001	−0.020	(0.047)	0.674	−0.126	(0.034)

Notes: Ns (unweighted): 8th grade 26,079; 10th grade 24,287; 12th grade 11,765. Each model contained 2 continuous outcomes: frequency of getting at least 7 hours of sleep per night, and a single substance use frequency measure. Bivariate models contained no measures other than sleep frequency and a single drug use frequency. Sleep frequency measured as never (1), seldom (2), sometimes (3), most days (4), nearly every day/every day (5). Cigarette use frequency in the past 30 days measured as: 0 (1), <1 cigarette (2), 1–5 cigarettes (3), 1/2 pack (4), 1 pack (5), 1 and 1/2 packs (6), 2 or more packs (7). For 10th and 12th grades, multi-group comparisons were significant at $p < .001$; for 8th grade, comparisons were significant at $p = .001$.

Table 4

Standardized Multivariate Path Analysis Correlations between Frequency of Getting at Least 7 Hours of Sleep and Substance Use: US Secondary Students, 2010–2014

	Grade 8			Grade 10			Grade 12		
	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>
<u>Sleep and past 12-month alcohol use</u>									
Bivariate	–0.167	(0.010)	<.001	–0.078	(0.009)	<.001	–0.046	(0.014)	0.001
Sociodemographic covariates ^a	–0.156	(0.010)	<.001	–0.081	(0.009)	<.001	–0.052	(0.013)	<.001
General health covariates ^b	–0.118	(0.010)	<.001	–0.056	(0.008)	<.001	–0.034	(0.013)	0.007
Academic performance covariates ^c	–0.136	(0.010)	<.001	–0.056	(0.009)	<.001	–0.033	(0.014)	0.016
Non-academic time use covariates ^d	–0.173	(0.010)	<.001	–0.091	(0.008)	<.001	–0.053	(0.013)	<.001
Deviance covariates ^e	–0.086	(0.010)	<.001	–0.032	(0.009)	<.001	–0.006	(0.014)	0.656
Psychosocial covariates ^f	–0.101	(0.010)	<.001	–0.043	(0.009)	<.001	–0.037	(0.014)	0.009
Full model	–0.039	(0.010)	<.001	–0.013	(0.008)	0.127	–0.008	(0.013)	0.541
<u>Sleep and past 12-month amphetamine use</u>									
Bivariate	–0.100	(0.009)	<.001	–0.084	(0.008)	<.001	–0.046	(0.012)	<.001
Sociodemographic covariates	–0.090	(0.009)	<.001	–0.084	(0.008)	<.001	–0.048	(0.012)	<.001
General health covariates	–0.069	(0.009)	<.001	–0.060	(0.008)	<.001	–0.019	(0.011)	0.094
Academic performance covariates	–0.081	(0.009)	<.001	–0.069	(0.008)	<.001	–0.036	(0.011)	0.002
Non-academic time use covariates	–0.100	(0.009)	<.001	–0.089	(0.008)	<.001	–0.053	(0.011)	<.001
Deviance covariates	–0.047	(0.009)	<.001	–0.053	(0.008)	<.001	–0.019	(0.012)	0.105
Psychosocial covariates	–0.055	(0.009)	<.001	–0.052	(0.008)	<.001	–0.025	(0.012)	0.039
Full model	–0.020	(0.009)	0.019	–0.030	(0.008)	<.001	0.003	(0.012)	0.775
<u>Sleep and past 30-day cigarette use</u>									
Bivariate	–0.115	(0.010)	<.001	–0.100	(0.009)	<.001	–0.120	(0.014)	<.001
Sociodemographic covariates	–0.103	(0.010)	<.001	–0.103	(0.009)	<.001	–0.122	(0.015)	<.001
General health covariates	–0.075	(0.010)	<.001	–0.050	(0.009)	<.001	–0.045	(0.014)	0.001
Academic performance covariates	–0.087	(0.010)	<.001	–0.077	(0.009)	<.001	–0.099	(0.014)	<.001
Non-academic time use covariates	–0.117	(0.010)	<.001	–0.108	(0.009)	<.001	–0.125	(0.015)	<.001
Deviance covariates	–0.050	(0.010)	<.001	–0.066	(0.009)	<.001	–0.092	(0.015)	<.001

	Grade 8			Grade 10			Grade 12		
	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>	<i>r</i>	(SE)	<i>p</i>
Psychosocial covariates	-0.065	(0.011)	<.001	-0.063	(0.009)	<.001	-0.089	(0.015)	<.001
Full model	-0.016	(0.010)	0.112	-0.028	(0.009)	0.001	-0.029	(0.014)	0.048
<u>Sleep and past 12-month marijuana use</u>									
Bivariate	-0.138	(0.010)	<.001	-0.088	(0.008)	<.001	-0.055	(0.013)	<.001
Sociodemographic covariates	-0.124	(0.010)	<.001	-0.091	(0.008)	<.001	-0.056	(0.013)	<.001
General health covariates	-0.091	(0.009)	<.001	-0.044	(0.008)	<.001	-0.005	(0.013)	0.709
Academic performance covariates	-0.100	(0.010)	<.001	-0.056	(0.008)	<.001	-0.035	(0.013)	0.008
Non-academic time use covariates	-0.141	(0.010)	<.001	-0.100	(0.008)	<.001	-0.068	(0.013)	<.001
Deviance covariates	-0.053	(0.010)	<.001	-0.033	(0.009)	<.001	-0.012	(0.013)	0.352
Psychosocial covariates	-0.081	(0.010)	<.001	-0.048	(0.008)	<.001	-0.032	(0.014)	0.020
Full model	-0.022	(0.009)	0.021	-0.005	(0.009)	0.552	0.023	(0.013)	0.067
<u>Sleep and past 12-month use of narcotics other than heroin</u>									
Bivariate	-0.094	(0.010)	<.001	-0.065	(0.007)	<.001	-0.042	(0.014)	0.002
Sociodemographic covariates	-0.089	(0.010)	<.001	-0.069	(0.007)	<.001	-0.049	(0.013)	<.001
General health covariates	-0.072	(0.010)	<.001	-0.048	(0.008)	<.001	-0.020	(0.014)	0.145
Academic performance covariates	-0.080	(0.010)	<.001	-0.052	(0.007)	<.001	-0.036	(0.013)	0.007
Non-academic time use covariates	-0.095	(0.010)	<.001	-0.071	(0.007)	<.001	-0.050	(0.013)	<.001
Deviance covariates	-0.043	(0.010)	<.001	-0.033	(0.007)	<.001	-0.017	(0.014)	0.238
Psychosocial covariates	-0.065	(0.010)	<.001	-0.036	(0.007)	<.001	-0.032	(0.014)	0.018
Full model	-0.034	(0.010)	0.001	-0.019	(0.008)	0.012	-0.006	(0.014)	0.681

Notes: Ns (unweighted) for 2010–2014; 8th grade 26,079; 10th grade 24,287; 12th grade 11,765. Several covariates were available on only one of the 2 12th grade questionnaire forms including sleep; models reported here limited to students responding to the given form. Each model contained 2 continuous outcomes (sleep and a single substance use frequency measure). Bivariate models contained no additional measures. Other models included direct paths between each outcome and year (using dummy indicators) and the specified domain covariates (estimates for individual covariates not shown here). In the full model, all covariate domains were included simultaneously.

^a Sex; race/ethnicity; 2-parent household; average parental education; region; population density.

^b Frequency of eating breakfast; frequency of eating at least some green vegetables or fruit; frequency of exercising vigorously.

^c Average academic grades; plans to graduate from a 4-year college.

^d Average hours worked per week during the school year; evenings out for fun/recreation.

^e Truancy; interpersonal aggression scale; theft and property damage scale.

Self-esteem scale; risk preference scale.

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