Prospective Relationship Between Poor Sleep and Substance-Related Problems in a National Sample of Adolescents

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Background: Previous studies showed that poor sleep prospectively predicted alcohol-related problems and illicit drug use in adolescents and young adults (Wong and Brower, 2012; Wong et al., 2010). However, more work needs to be done to elucidate the nature of these problems. The purpose of this study was to examine whether sleep difficulties and hours of sleep prospectively predicted several serious substance-related problems, for example, binge drinking, driving under the influence of alcohol, and risky sexual behavior.

Methods: Study participants were 6,504 adolescents from the National Longitudinal Study of Adolescent Health. Data were collected from interviews and questionnaires. This study analyzed data from the first 3 waves of data (T1: 1994 to 1995; T2: 1996; T3: 2001 to 2002). In all analyses, we used sleep difficulties at a previous wave to predict substance-related problems at a subsequent wave, while controlling for substance-related problems at a previous wave.

Results: Holding T1 alcohol-related problems constant, sleep difficulties at T1 significantly predicted alcohol-related interpersonal problems, binge drinking, gotten drunk or very high on alcohol, driving under the influence of alcohol, getting into a sexual situation one later regretted due to drinking, ever using any illicit drugs, and drug-related problems at T2. T1 hours of sleep negatively predicted T2 alcohol-related interpersonal problems and binge drinking. The relationship between T2 sleep variables and T3 substance-related problems was consistent with previous waves, although the effect was weaker.

Conclusions: Sleep difficulties and hours of sleep are a significant predictor of a number of substance-related problems. It may be useful to educate adolescents about the importance of sleep, sleep hygiene, and the potential consequences of poor sleep on drinking and related behaviors.

Key Words: Sleep Difficulties, Alcohol-Related Problems, Illicit Drug Use, Adolescents.

BOTH SLEEP PROBLEMS and substance use are important public health issues in the United States (Centers for Disease Control and Prevention, 2014a,b). Sleep difficulties and insufficient sleep are common among our nation's youth. National polls indicated that 27% of school-aged children (Mindell et al., 2004) and 45% of adolescents did not sleep enough (Carskadon et al., 2006). Other studies showed that about 1 in 10 adolescents had trouble falling asleep or staying asleep almost every day or every day in the last 12 months (Roane and Taylor, 2008; Wong and Brower, 2012). According to data from the Monitoring the Future study in 2013 (Johnston et al., 2014), 10% of eighth graders and 39% of 12th graders used alcohol in the past 30 days. The figures for illicit drug use are lower but still alarming. Eight percent of eighth graders and 25% of 12th graders reported using 1 or more illicit drugs in the last 30 days. Growing literature suggests that sleep difficulties and insomnia are important risk factors for substance use and abuse onset (Breslau et al., 1996; Weissman et al., 1997; Wong et al., 2009, 2010). The main goal of this study was to add to this literature by systematically examining the longitudinal relationships between sleep difficulties, hours of sleep, and substance-related problems.

The longitudinal relationship between poor sleep and substance use has been reported in both normal and clinical populations of adults. Data from the Epidemiological Catchment Survey (N = 18,571) showed that adults with insomnia in the past year without any psychiatric disorder were more likely to experience the first onset of alcohol use during the following year (Weissman et al., 1997). A large epidemiological study of a random sample of young adults in Michigan (N = 979) reported that insomnia increased the risk of any illicit drug use disorder and nicotine dependence 3.5 years later (Breslau et al., 1996). Sleep problems are also more common among alcoholics than nonalcoholics (Brower, 2001). One study found that among adults who received treatment for alcohol dependence (N = 172), those with insomnia were more likely to use alcohol as a sleep aid and had longer sleep onset latency (time between going to bed

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and sleep onset) and lower sleep efficiency (percent time in bed sleeping) than those without insomnia (Brower et al., 2001). A subset of these patients ($N = 74$) had a follow-up 5 months after treatment. Alcoholics with baseline insomnia were more likely to relapse to alcohol use (Brower et al., 2001).

The association between poor sleep and substance use has also been found in younger age groups. One study examined the relationship between childhood sleep problems and onset of substance use in boys ($N = 258$) (Wong et al., 2004). Controlling for parental alcoholism, sleep problems (maternal ratings of having trouble sleeping and overtiredness) from ages 3 to 5 significantly predicted onset of any use of alcohol, marijuana, and illicit drugs, and onset of occasional or regular use of cigarettes by ages 12 to 14. Parental alcoholism was not associated with children's sleep problems. In a subsequent study of a larger mixed-gender sample ($N = 386$; 292 boys, 94 girls), sleep problems at ages 3 to 8 increased the probability of drinking onset among boys prior to 15 years old. For girls, sleep problems did not significantly increase the hazard probability of drinking onset until they were 15 or older (Wong et al., 2009).

In a follow-up study of the same sample (Wong et al., 2010), having trouble sleeping in childhood predicted a higher probability of "having trouble sleeping" in adolescence, which in turn predicted the presence of drug-related problems in young adulthood (18 to 20 years old). Overtiredness in childhood predicted lower response inhibition in adolescence, which in turn predicted number of illicit drugs used in young adulthood. Overtiredness in childhood also directly predicted the presence of binge drinking, blackouts, driving after drinking alcohol, and number of lifetime alcohol problems in young adulthood. Gender and parental alcoholism did not moderate the relationship between sleep and substance-related problems. To our knowledge, this is the first study showing a long-term relationship between childhood sleep measures and subsequent substance-related problems. The longitudinal relationship between sleep difficulties and lower response inhibition in this study was consistent with previous research showing that experimental manipulated sleep deprivation was associated with lower inhibition in children and adults (Drummond and Brown, 2001; Durmer and Dinges, 2005; Pilcher and Huffcutt, 1996).

The relationship between poor sleep and substance use has been demonstrated in nationally representative samples of adolescents. Concurrent associations between insomnia (defined as having trouble falling asleep or staying asleep almost every day or every day in the last 12 months) and substance use were reported in the National Longitudinal Study of Adolescent Health (ADD HEALTH; $N = 4{,}494$) (Roane and Taylor, 2008), the largest national study of adolescents in the United States (Harris et al., 2014). Adolescents in the insomnia group were more likely than the no insomnia group to report using alcohol, cannabis, and other illicit drugs at time 1 (Roane and Taylor, 2008). However, longitudinal analyses using T1 insomnia to predict T2 new incidence of substance use did not find any significant relationship. The stringent definition of insomnia and the exclusion of adolescents who used substances in T1 might have accounted for these findings.

Another study using ADD HEALTH data reported that the frequency of having trouble falling asleep or staying asleep in the last 12 months at a previous wave increased the likelihood of one or more of the following alcohol-related problems ($N = 6{,}504$) (Wong and Brower, 2012)—having problems at school or with school work, having problems with friends, having problems with someone they were dating, and getting into a physical fight over the last 12 months due to their drinking at T2 and T3. However, because substance use was not a focus of the study, the relationships between sleep difficulties and a number of important substance-related problems were not analyzed.

The main goal of this study was to systematically examine the prospective relationship between sleep difficulties/insufficient sleep and problems related to alcohol and other illicit drugs. As we stated earlier, most existing studies on sleep difficulties and substance use focused on having trouble sleeping or insomnia (clinical definition) as risk factors, assuming that those who had trouble sleeping would not have sufficient sleep. However, individuals might not have sufficient sleep even if they have no problems sleeping. As we pointed out earlier, national data indicated that many adolescents (as much as 45%) did not get enough sleep (Carskadon et al., 2006). In this study, we want to independently assess the effects of these 2 sleep variables (i.e., having trouble sleeping/staying asleep and hours of sleep) on subsequent alcohol- and drug-related problems. Understanding the relationships between poor sleep/perceived tiredness and substance-related problems may have important implications for prevention and intervention programs for our nation's youth.

MATERIALS AND METHODS

Participants

Participants in the study were 6,504 adolescents and young adults from the publicly accessible database of ADD HEALTH (Harris et al., 2014). ADD HEALTH is the largest nationally representative sample of U.S. adolescents. The study was designed to examine health-related behaviors, social contexts, and health-related outcomes in adolescents and young adults. The publicly accessible database included one-half of the core sample who completed an in-home interview and an oversample of African American adolescents who had a parent with a college degree. Time 1 of data collection took part in 1994 to 1995 ($\overline{age} = 15.99(1.75)$). Time 2 occurred 1 year later, in 1996 ($\overline{age} = 16.02(1.62)$). Time 3 took part 5 years after time 2, in 2001 to 2002 ($\overline{age} = 21.82(1.81)$) (Harris et al., 2014). Data on sleep problems, substance use, and other important covariates from T1 to T3 were analyzed in this paper.

Measures

Sleep difficulties were measured by the question, "Please tell me how often you have had each of the following conditions in the past 12 months — Trouble falling asleep or staying asleep?" Responses

were given on a 5-point rating scale — 0 = never, 1 = a few times, 2 = once a week, 3 = almost every day, and 4 = every day. Hours of sleep were measured by the question, "How many hours of sleep do you usually get?" Both sleep measures were available at T1 and T2.

We selected substance-related problems that potentially had serious social or health consequences for adolescents. Four types of alcohol-related problems were examined—interpersonal problems, binge drinking, driving under the influence of alcohol, and getting into a sexual situation one later regretted due to drinking. Interpersonal problems included problems with parents, friends, dating, and getting into a physical fight due to drinking. They were measured by the following questions with the stem "Over the past 12 months…," "…have you gotten into trouble with your parents because you had been drinking?," "…have you had problems at school or with school work because you had been drinking?," "…have you had problems with your friends because you had been drinking?," "…have you had problems with someone you were dating because you had been drinking?," "…did you get into a physical fight because you had been drinking?" Participants were asked to select 1 of the 5 choices, "never," "once," "twice," "3 to 4 times," or "5 or more times." In addition, we selected 3 alcohol-related problems—binge drinking ("Over the past 12 months, on how many days did you drink 5 or more drinks in a row?"), driving while being drunk ("Have you ever driven while drunk?)" [T1] and "Since (last interview), have you ever driven while drunk?" [T2 and T3], and engaging in sexual activities that one later regretted due to drinking ("Over the past 12 months, did you get into a sexual situation that you later regretted because you had been drinking?"). On the binge drinking question, participants were asked to select 1 of the 7 choices, from "never" to "every day or almost every day." On questions related to driving while being drunk and regretted sexual activities, participants were asked to respond either "yes" (coded as 1) or "no" (coded as 0). All alcohol-related problems were later recoded into a dichotomous variable (0 = no; 1 = yes). Data were available on all alcohol-related problems at all 3 times.

Compared to alcohol-related problems, there are fewer questions on drug-related problems in ADD HEALTH. These questions also change from T1, T2, and T3. At T1, drug-related problems were measured by 3 questions—"Have you driven high on drugs?," "Have you been high on drugs at school?," "Have you gotten into a fight when you had been using drugs?" At T2, the same 3 items were used, with the stem "Since (last interview)" added to each question. Participants were asked to respond "yes" (coded as 1) or "no" (coded as 0) to the above questions. At T3, participants were asked to answer 5 different questions with the stem "Over the past 12 months…" They included, "…have you had problems at school or with school work because you had been using drugs?," "…have you had problems with your friends because you had been using drugs?," "…have you had problems with someone you were dating because you had been using drugs?," "…did you get into a sexual situation that you later regretted because you had been on drugs?," and "…did you get into a physical fight because you had been on drugs?" Participants were asked to select 1 of the 5 choices, "never," "once," "twice," "3 to 4 times," or "5 or more times." Similar to the coding of alcohol-related problems, all ordinal measures of drug-related problems were recoded into dichotomous variables (0 = absence; 1 = presence) due to the highly skewed distributions for most variables.

Due to the potential serious consequences of illicit drug use on the physical and mental health of adolescents (Castellanos-Ryan et al., 2013; Swendsen et al., 2012), we also examined the relationship between the 2 sleep measures and the likelihood of illicit drug use. Data on lifetime illicit drug use (0 = no; 1 = yes) were obtained from 4 questions from the substance use section—"During your life, how many times have you used marijuana?" The same question was used to get information on other drugs by substituting the word marijuana with 3 other drugs, that is, cocaine, inhalants, or other illegal drugs (e.g., LSD, speed, and heroin). Data on these 4 questions were available on all 3 waves.

Covariates that may be associated with sleep difficulties or substance-related problems were controlled for in the analyses (Johnston et al., 2014; Windle and Zucker, 2010), as they may potentially confound the relationship between them. These include gender (1 = male, 2 = female), age, race (0 = non-Caucasian, 1 = Caucasian), grade at school, poverty (0 = did not receive public assistance, 1 = received public assistance), and chronic health problems (0 = absence of any health problems including allergies, asthma, migraines, diabetes, or obesity, 1 = presence of any health problems).

Analytic Plan

First, we examined the concurrent relationship between sleep difficulties/hours of sleep and substance-related problems at each wave using chi-square analyses and bivariate logistic regression models. Next, we tested the longitudinal relationships between insomnia and substance-related problems. Multivariate logistic regression models were used to predict substance-related problems at T2 and T3. Sleep difficulties and hours of sleep at a previous wave were the primary predictors of interest. Gender, age, ethnicity, school grade, poverty, and chronic health problems were used in the analyses as statistical controls. In all analyses, we controlled for the specific substance-related problems in the previous wave. Thus, the analyses examined whether sleep problems predicted changes of alcohol- and drug-related problems over time.

RESULTS

Descriptive Statistics

Approximately 1 in 5 adolescents reported having 1 or more alcohol-related interpersonal problems at T1 (18.5%), T2 (18.3%), and T3 (18.4%). About one-quarter reported binge drinking at T1 (25.8%) and T2 (28.1%), while close to half of participants (48.4%) reported binge drinking at T3. In addition, 6.4% at T1 and 5.4% at T2 reported having driven while drunk at least once. At T3, the figure increased to 24%. Moreover, 7.9% at T1 and 7.3% at T2 reported engaging in sexual activities they later regretted due to drinking. This percentage almost doubled (14.3%) at T3.

Concurrent Relationships Between Sleep Measures and Substance-Related Problems

The concurrent relationships between having trouble sleeping/staying asleep and substance-related problems were described in Table 1. At T1, when compared to their counterparts, adolescents who had sleep difficulties once a week, every day, or almost every day in the last 12 months were approximately 47% more likely to have alcohol-related interpersonal problems, 47% more likely to engage in binge drinking, and 80% more likely to engage in regretted sexual activities. The relationship between sleep difficulties and driving while being drunk was not significant. At T2, adolescents

who had trouble sleeping were approximately 71% more likely to have alcohol-related interpersonal problems, 65% more likely to engage in binge drinking, 57% more likely to have driven while drunk, and 92% more likely to engage in regretted sexual activities.

Hours of sleep were significantly associated with substance-related problems within the same wave. At both T1 and T2, hours of sleep had a significant negative relationship with alcohol-related interpersonal problems. In other words, fewer hours of sleep were associated with a greater odds of alcohol-related interpersonal problems (T1: Wald χ^2 (1) = 54.11, OR = 0.84, $p < 0.001$; T2: Wald χ^2 (1) = 31.52, OR = 0.86, $p < 0.001$), binge drinking (T1: Wald χ^2 (1) = 85.99, OR = 0.82, $p < 0.001$; T2: Wald χ^2 (1) = 26.67, OR = 0.89, $p < 0.001$), driving while being drunk (T1: Wald χ^2 (1) = 38.91, OR = 0.80, $p < 0.001$; T2: Wald χ^2 (1) = 11.85, OR = 0.85, $p < 0.001$), and engaging in sexual activities one later regretted due to drinking (T1: Wald χ^2 (1) = 38.22, OR = 0.81, $p < 0.001$; T2: Wald χ^2 (1) = 12.81, OR = 0.87, $p < 0.001$). Hours of sleep also had a significant concurrent relationship with the likelihood of ever using illicit drugs (T1: Wald χ^2 (1) = 50.10, OR = 0.87, $p < 0.001$; T2: Wald χ^2 (1) = 22.42, OR = 0.90, $p < 0.001$) and drug-related problems (T1: Wald χ^2 (1) = 65.02, OR = 0.80, $p < 0.001$; T2: Wald χ^2 (1) = 30.09, OR = 0.83, $p < 0.001$).

Longitudinal Relationships Between Sleep and Substance-Related Problems

Alcohol-related problems at a previous wave strongly predicted alcohol-related problems at a subsequent wave (Table 2). Moreover, Caucasian adolescents were more likely to report having any alcohol-related problems than non-Caucasian adolescents at both T2 and T3. Women and older adolescents were less likely to report alcohol-related interpersonal problems, binge drinking, driving while drunk, and regretted sexual activities due to drinking at T3. An increase in education was associated with an increase in the odds of binge drinking and driving while drunk at T2, as well as an increase in the odds of binge drinking at T3. Adolescents who received public assistance were less likely to engage in binge drinking at T3.

Controlling for T1 alcohol-related problems and demographics covariates, T1 sleep difficulties and hours of sleep predicted T2 interpersonal problems. As trouble sleeping at T1 increased by 1 unit, participants were 11% more likely to report alcohol-related interpersonal problems at T2. Additionally, as hours of sleep increased by 1 unit, participants were 8% less likely to report interpersonal problems at T2. With respect to binge drinking, a 1-hour increase in sleep was associated with a 9% decrease in the odds of binge drinking. Neither sleep difficulties nor hours of sleep at T1 predicted driving while drunk at T2. When we dropped the sleep variable with a smaller Wald χ^2 (i.e., hours of sleep), sleep difficulties became a significant predictor of driving while drunk. A unit increase in the frequency of having trouble sleeping was associated with a 16% increase in drunk driving. T1 sleep difficulties predicted engaging in regretted sexual activities due to drinking at T2. As having trouble sleeping increased by 1 unit, the odds of reporting regret in sexual activities increased by about 14%.

T2 sleep difficulties significantly predicted T3 interpersonal problems. An increase in 1 unit of sleep difficulties was associated with a 10% increase in the odds of interpersonal problems at T2 and a 10% increase in the odds of driving while drunk at T3. Hours of sleep at T2 did not independently predict interpersonal problems at T3. Neither sleep difficulties nor hours of sleep at T2 predicted binge drinking or regretted sexual activities at T3. However, when sleep difficulties were deleted from the model, hours of sleep significantly predicted

Table 1. The Concurrent Relationship Between Sleep Difficulties and Alcohol-Related/Drug-Related Problems at Different Waves

	Interpersonal		Binge drinking		Driving while drunk		Regretted sex		Ever used illicit drugs		Drug-related problems	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Trouble falling asleep (T1)[a]												
Time 1												
No (*N* = 5011)	855/5011	17.1	1201/5001	24.0	305/5005	6.1	341/5007	6.8	1319/4921	26.8	538/5008	10.7
Yes (*N* = 1485)	345/1485	23.2	470/1479	31.7	109/1483	7.3	172/1484	11.6	552/1467	37.6	276/1485	18.6
χ^2	28.95***		35.94***		3.02		35.93***		63.93***		64.26***	
Odds ratio	1.47***		1.47***		1.22		1.80***		1.65***		1.90***	
95% CI	1.27 to 1.70		1.30 to 1.67		0.97 to 1.53		1.48 to 2.17		1.46 to 1.86		1.62 to 2.22	
Trouble falling asleep (T2)[a]												
Time 2												
No (*N* = 3672)	595/3668	16.2	935/3657	25.6	175/3667	4.7	223/3668	6.3	857/3638	23.6	347/3669	9.5
Yes (*N* = 1161)	288/1159	24.8	418/1157	36.1	85/1161	7.3	128/1159	11.0	438/1154	38	205/1161	17.7
χ^2	43.86***		48.51***		11.25***		32.19***		92.09***		58.58***	
Odds ratio	1.71***		1.65***		1.57***		1.92		1.96***		2.05***	
95% CI	1.46 to 2.00		1.43 to 1.90		1.21 to 2.10		1.53 to 2.41		1.72 to 2.29		1.70 to 2.48	

[a]Trouble falling asleep or staying asleep in the last 12 months once a week, every day, or almost every day.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Nondrinkers and nondrug users are coded as having no alcohol-related or drug-related problems.
Wave 3 data were not included in this table because there was no item about having trouble falling asleep or staying asleep.

Table 2. The Prospective Relationship Between Sleep Measures and Alcohol-Related Problems

	Interpersonal problems			Binge drinking			Driving when drunk			Regretted sex		
Variable	Wald χ^2	Odds ratio	95% CI	Wald χ^2	Odds ratio	95% CI	Wald χ^2	Odds ratio	95% CI	Wald χ^2	Odds ratio	95% CI
Time 2												
Gender	0.05	0.98	0.82 to 1.17	2.90	0.87	0.74 to 1.02	14.33	0.54***	0.93 to 0.74	0.15	0.95	0.74 to 1.23
Age	0.82	1.06	0.94 to 1.20	0.13	0.98	0.88 to 1.10	0.37	0.94	0.75 to 1.16	1.62	1.13	0.94 to 1.35
Race-ethnicity	14.45	1.50***	1.22 to 1.85	56.65	2.13***	1.76 to 2.60	5.82	1.62*	1.10 to 2.41	8.77	1.62**	1.18 to 2.22
Education	1.79	1.10	0.96 to 1.26	11.77	1.24**	1.10 to 1.40	15.50	1.64***	1.28 to 2.10	0.23	1.05	0.86 to 1.28
Poverty status	0.26	0.93	0.72 to 1.22	1.04	0.089	0.70 to 1.12	2.20	0.59	0.29 to 1.19	0.01	1.02	0.71 to 1.46
Chronic health conditions	0.77	0.92	0.78 to 1.10	0.01	0.099	0.85 to 1.16	0.89	0.88	0.66 to 1.21	2.64	0.81	0.63 to 1.05
Alcohol-related problems (Time 1)[a]	429.81	7.25***	6.01 to 8.75	561.65	7.97***	6.71 to 9.47	145.27	10.36***	7.08 to 15.14	214.17	8.89***	6.64 to 11.92
Trouble falling asleep (Time 1)[b]	6.37	1.11**	1.02 to 1.21	0.65	1.03	0.96 to 1.12	3.14	1.14[c]	0.99 to 1.32	4.68	1.14*	1.01 to 1.28
Hours of sleep	5.95	0.92**	0.86 to 0.98	10.59	0.91**	0.85 to 0.96	1.31	0.93	0.83 to 1.05	1.18	0.94	0.85 to 1.03
Time 3												
Gender	58.93	0.49***	0.41 to 0.59	106.20	0.45***	0.39 to 0.53	113.19	0.39***	0.33 to 0.47	37.33	0.54***	0.45 to 0.66
Age	4.26	0.87*	0.77 to 0.99	11.83	0.83**	0.75 to 0.92	13.29	0.79***	0.70 to 0.90	3.92	0.87*	0.75 to 1.00
Race-ethnicity	22.93	1.70***	1.37 to 2.11	145.63	2.81***	2.38 to 3.33	71.65	2.55***	2.05 to 3.16	45.34	2.46***	1.89 to 3.20
Education	0.93	1.10	0.93 to 1.23	13.23	1.24***	1.11 to 1.40	16.71	1.33	1.16 to 1.52	1.24	1.09	0.94 to 1.28
Poverty status	0.73	0.88	0.66 to 1.18	11.51	0.65**	0.51 to 0.84	0.36	0.92	0.71 to 1.20	0.88	0.85	0.61 to 1.19
Chronic health conditions	1.45	0.90	0.75 to 1.08	1.23	0.92	0.79 to 1.07	2.99	0.84	0.73 to 1.02	0.95	0.91	0.75 to 1.10
Alcohol-related problems (Time 2)[a]	74.13	2.51**	2.03 to 3.09	96.04	2.40***	2.02 to 2.86	59.36	3.91***	2.76 to 5.53	27.95	2.32***	1.70 to 3.18
Trouble falling asleep (Time 2)[b]	3.92	1.10*	1.00 to 1.21	3.01	1.07	0.99 to 1.61	4.01	1.10*	1.00 to 1.20	2.85	1.09[d]	0.99 to 1.21
Hours of sleep	1.77	0.96	0.89 to 1.02	0.06	0.99	0.94 to 1.05	3.45	0.94	0.88 to 1.00	3.61	0.93[e]	0.86 to 1.00

[a]Corresponding alcohol-related problems (e.g., interpersonal problems) in a previous wave were controlled for in the analyses.
[b]Frequency of trouble falling asleep or staying asleep in the last 12 months.
[c]Significant when hours of sleep were dropped from the model, Wald χ^2 (1) = 3.92, OR = 1.16, $p < 0.05$.
[d]Significant when hours of sleep were dropped from the model, Wald χ^2 (1) = 3.90, OR = 1.11, $p < 0.05$.
[e]Significant when trouble of sleeping was dropped from the model, Wald χ^2 (1) = 4.58, OR = 0.92, $p < 0.05$.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

regretted sex due to drinking. A unit increase in hours of sleep was associated with about an 8% decrease in the risk of having regretted sex due to drinking. Alternatively, when hours of sleep were dropped from the analyses, sleep difficulties became a significant predictor. A unit increase in sleep difficulties increases the odds of interpersonal problems by 11%.

Drug-Related Problems

Similar to the results on alcohol-related problems, drug-related problems at a previous wave were the most significant predictor of drug-related problems at a subsequent wave (Table 3). Controlling for previous drug use experience and drug-related problems, hours of sleep at T2 significantly predicted lifetime illicit drug use and experience of any drug-related problems at T3. One unit increase in hours of sleep was associated with an approximately 7% increase in odds of ever using illicit drugs and an 8% increase in odds of experiencing any drug-related problems. Sleep difficulties at T2 also predicted the odds of ever using any illicit drugs. An increase in 1 unit of sleep difficulties was related to about 10% increase in the odds of ever using any illicit drugs. Neither T2 sleep variables had any significant relationship with the odds of ever using any illicit drugs and experiencing any drug-related problems at T3. Other than drug-related problems at T2, several demographic variables predicted lifetime drug use and drug-related problems at T3. Women were less likely than men to use illicit drugs or experience any drug-related problems. Compared to younger participants, older

Table 3. The Prospective Relationship Between Perceived Tiredness and Drug-Related Problems

	Drug-related problems			Ever used illicit drugs		
Variable	Wald χ^2	Odds ratio	95% CI	Wald χ^2	Odds ratio	95% CI
Time 2						
Gender	0.99	0.89	0.72 to 1.12	1.07	1.09	0.92 to 1.29
Age	0.90	0.93	0.80 to 1.08	0.78	0.95	0.84 to 1.07
Race-ethnicity	0.45	1.09	0.85 to 1.40	0.07	0.98	0.81 to 1.18
Education	3.69	1.18	1.00 to 1.40	0.83	1.06	0.93 to 1.21
Poverty status	1.22	0.83	0.60 to 1.16	0.17	0.95	0.76 to 1.20
Chronic health conditions	0.14	1.04	0.84 to 1.30	0.39	1.05	0.89 to 1.25
Drug-related problems (Time 1)[a]	496.32	15.03***	11.84 to 19.08	858.68	13.14***	11.06 to 15.62
Trouble falling asleep (Time 1)[b]	1.90	1.08	0.97 to 1.19	5.60	1.10*	1.02 to 1.19
Hours of sleep	4.39	0.92*	0.85 to 0.99	5.82	0.93*	0.87 to 0.99
Time 3						
Gender	26.44	0.47***	0.35 to 0.63	48.61	0.58***	0.45 to 0.67
Age	3.72	0.82*	0.67 to 1.00	17.53	0.79***	0.71 to 0.88
Race-ethnicity	1.83	1.25	0.91 to 1.73	29.96	1.63***	1.37 to 1.95
Education	0.44	0.93	0.74 to 1.16	1.70	1.08	0.96 to 1.22
Poverty status	0.39	0.86	0.55 to 1.36	2.57	0.82	0.65 to 1.05
Chronic health conditions	1.23	1.17	0.89 to 1.55	0.47	0.95	0.81 to 1.10
Drug-related problems (Time 2)[a]	69.29	4.23***	3.01 to 5.95	201.45	3.46***	2.91 to 4.11
Trouble falling asleep (Time 2)[b]	1.66	1.10	0.95 to 1.27	2.32	1.07	0.98 to 1.16
Hours of sleep	0.30	1.03	0.93 to 1.14	1.04	0.97	0.92 to 1.03

[a]Drug-related problems or the experience of using illicit drugs in a previous wave were controlled for in the analyses.
[b]Frequency of trouble falling asleep or staying asleep in the last 12 months.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

participants were less likely to use any illicit drugs or to have any drug-related problems. Additionally, Caucasian participants were more likely than other ethnic groups to use illicit drugs.

DISCUSSION

Recent studies indicated that sleep problems are a risk factor for onset of alcohol use and alcohol-related problems, and alcohol abuse across different developmental periods (Breslau et al., 1996; Weissman et al., 1997; Wong et al., 2004, 2009, 2010). However, the studies on adolescents were mostly drawn from high risk samples. This study added to the existing literature by establishing the relationship between 2 sleep variables (i.e., sleep difficulties and hours of sleep) and the odds of serious alcohol- and drug-related problems in a nationally representative sample. Although sleep difficulties (i.e., having trouble falling asleep or staying asleep) were by definition correlated with fewer hours of sleep, adolescents may have insufficient sleep due to a variety of reasons including academic and social obligations, poor sleep hygiene, and 24/7 Internet access through phones and computers (National Sleep Foundation, 2006, 2011).

Results indicated that both sleep variables are predictive of substance-related problems. Specifically, trouble falling asleep at T1 positively predicted the odds of alcohol-related interpersonal problems, binge drinking, driving while drunk, regretting sexual activities due to drinking, illicit drug use, and drug-related problems due to drinking at T2. Trouble falling asleep at T2 also significantly predicted T3 alcohol-related interpersonal problems, driving while drunk, and regretting sexual activities. Controlling for sleep difficulties, more hours of sleep at T1 were associated with a lower risk of alcohol-related interpersonal problems and binge drinking at T2. Fewer hours of sleep at T2 were associated with the likelihood to engage in regretted sexual activities due to drinking at T3.

The weaker relationship between T2 sleep variables and T3 substance-related problems was probably due to the longer time lapse between data collection times—T1 and T2 are only 1 year apart, whereas T2 and T3 are 5 years apart. The longer time lapse might have weakened any temporal relationship between sleep variables and subsequent substance-related problems. Another possible reason is developmental change. Young adults (T3), especially those who finished college, may be less likely than adolescents (T1, T2) to engage in certain substance-related problems in part due to changes in contextual and peer influences. Nevertheless, the results in T2 and T3 are largely consistent with one another. Taken the results of this study and other recent studies together, sleep difficulties and insufficient sleep appear to be important risk factors for the onset of substance use and substance-related problems.

It is unclear what factors might explain this relationship. There is a growing body of literature showing that sleep problems may adversely impact control of affect, cognitive processes, and behavior. A meta-analysis of 19 empirical studies reported that sleep deprivation had the greatest negative effect on mood, followed by negative effects on cognitive and motor tasks (Pilcher and Huffcutt, 1996). In an experimental study, participants experienced less positive affect

and more anxiety in a catastrophizing task, rating the likelihood of potential catastrophes as higher when sleep deprived, compared to when rested (Talbot et al., 2010). The changes in positive and negative affect associated with sleep loss may make it difficult for adolescents to control their behavior.

Sleep problems also appear to adversely affect cognitive and neurocognitive processes. Sleep deprivation and fragmentation affects executive functions, working memory, and divergent cognitive tasks such as multitasking and flexible thinking (Durmer and Dinges, 2005; Pilcher and Huffcutt, 1996). There is evidence that sleep deprivation adversely affects inhibition among adults, including the ability to suppress a prepotent response (Chuah et al., 2006), detect error in a task (Tsai et al., 2005), and make good decisions involving distracting and unexpected information (Harrison and Horne, 2000). One longitudinal study found that early childhood sleep problems predicted lower response inhibition in adolescence, which increased the odds of having alcohol-related problems in young adulthood (Wong et al., 2010). The adverse impact of sleep deprivation on executive functions in general, and inhibitory processes in particular, may increase the likelihood of engaging in risk behaviors, such as the ones examined in the study (Blume et al., 2000; Giancola and Parker, 2001; Nigg et al., 2006).

Future research could focus on identifying self-regulatory processes that mediate the relationship between sleep difficulties and substance-related problems. One area that warrants more research is how sleep difficulties and deprivation may affect brain mechanisms, which in turn influence control of affect, cognitive processes, and behavior. Recent studies suggest that the association between sleep and self-regulatory processes might be partially explained by their relationship with the prefrontal cortex (PFC) (Horne, 2012; Walker and van der Helm, 2009; Yoo et al., 2007). PFC regulates affect, attention, and complex cognitive activities (Davidson et al., 2000; Posner and Petersen, 1990; Yang and Raine, 2009). Prolonged periods of wakefulness appear to affect the PFC (Horne, 1993, 2012). One study showed that after 35 hours of sleep deprivation, subjects experienced a loss of functional connectivity between the amygdala and the medial PFC compared to controls (Yoo et al., 2007). Future studies could examine how neural circuitries mediate the effect of sleep problems on self-regulation and risk behavior.

Another promising area of research involves the reciprocal relationship between sleep problems and self-regulation. A recent review showed bidirectional relationships between sleep and regulation of emotions (Baglioni et al., 2010)—while heightened emotional arousal contributes to the maintenance of sleep problems, dysfunction in the sleep–wake regulating neural circuitries also reinforces emotional disturbances.

Little is known about how the reciprocal relationships between sleep problems and related emotions change over time, especially in adolescence and young adulthood. How such emotions may moderate the relationship between sleep and problem substance use is also not well understood.

This study had several limitations. First, all sleep and substance use variables in this study were based on self-report, which are subject to response and recall bias. Future studies could include additional sleep measures such as polysomnography, actigraphy, and sleep hygiene. Data on biological confirmation of substance use such as urine drug tests would also be valuable. Second, sleep difficulties and hours of sleep were measured by 2 items only, as the primary focus of ADD HEALTH is not sleep. Researchers could include multiple sleep variables in future studies and explicitly estimate their measurement error by performing latent variable analyses. Third, establishing a temporal relationship between sleep problems/hours of sleep with substance-related problems does not explain why this relationship exists. Identifying mediators and moderators of this relationship is essential to fully understand the longitudinal relationship between sleep and substance-related problems. Previously, we found that response inhibition (a component of executive function) in adolescence significantly mediated the relationship between persistent sleep difficulties in childhood and illicit drug use in young adulthood. Future work could investigate whether other executive functions may meditate and moderate the relationship between sleep and substance use. Fourth, ADD HEALTH data were collected between 1994 and 2002. The findings need to be replicated in more recent national samples. Fifth, data regarding comorbid behavioral disorders were not examined. Thus, we could not control for the presence of these disorders in the analyses.

Both sleep and substance use are significant public health issues for our nation's youth. This study reported findings that link sleep difficulties and hours of sleep to several important substance-related problems in adolescence. Understanding the nature of this complex relationship and what factors may exacerbate or ameliorate it will be an important first step to the implementation of effective prevention and intervention programs.

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