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# Binge Drinking and Sleep Problems among Young Adults*

**Ioana Popovici**[a] and **Michael T. French**[b,**]

[a]Nova Southeastern University, College of Pharmacy, Department of Sociobehavioral and Administrative Pharmacy, 3200 South University Drive, Fort Lauderdale, FL, USA, 33328-2018; Telephone: 954-262-1393; Fax: 954-262-2278; Ioana.Popovici@nova.edu.

[b]Health Economics Research Group, Department of Sociology, Department of Epidemiology and Public Health, and Department of Economics, 5202 University Drive, Merrick Building, Room 121F, P.O. Box 248162, Coral Gables, FL, USA, 33124-2030; Telephone: 305-284-6039; Fax: 305-284-5310; mfrench@miami.edu.

## Abstract

**Objective—**As most of the literature exploring the relationships between alcohol use and sleep problems is descriptive and with small sample sizes, the present study seeks to provide new information on the topic by employing a large, nationally representative dataset with several waves of data and a broad set of measures for binge drinking and sleep problems.

**Methods—**We use data from the National Longitudinal Study of Adolescent Health (Add Health), a nationally representative survey of adolescents and young adults. The analysis sample consists of all Wave 4 observations without missing values for the sleep problems variables (N=14,089, 53% females). We estimate gender-specific multivariate probit models with a rich set of socioeconomic, demographic, physical, and mental health variables to control for confounding factors.

**Results—**Our results confirm that alcohol use, and specifically binge drinking, is positively and significantly associated with various types of sleep problems. The detrimental effects on sleep increase in magnitude with frequency of binge drinking, suggesting a dose-response relationship. Moreover, binge drinking is associated with sleep problems independent of psychiatric conditions.

**Conclusions—**The statistically strong association between sleep problems and binge drinking found in this study is a first step in understanding these relationships. Future research is needed to

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**Corresponding Author (and reprint requests)**: Michael T. French, Professor of Health Economics, University of Miami, Department of Sociology, 5202 University Drive, Merrick Building, Room 121F, P.O. Box 248162, Coral Gables, FL, 33124-2030; Telephone: 305-284-6039; Fax: 305-284-5310; mfrench@miami.edu.



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No conflict declared.

determine the causal links between alcohol misuse and sleep problems to inform appropriate clinical and policy responses.

**Keywords**

Alcohol use; Binge Drinking; Sleep Problems; National Longitudinal Study of Adolescent Health (Add Health)

## 1. INTRODUCTION

Several studies have found significant associations between alcohol use and sleep disturbances (Roth, 2005; Vinson et al., 2010; Vitiello, 2006; Van Reen et al., 2011) as well as obstructive sleep apnea (OSA; Aldrich et al., 1993; Mamdani et al., 1989). Results of epidemiological and clinical studies show that alcohol use disorders are more prevalent in those with insomnia (Ford and Kamerow, 1989) and that individuals with alcohol abuse/dependence are more likely to suffer from sleep problems (Baekeland et al., 1974; Feuerlein, 1974; Caetano et al., 1998; Foster et al., 1998; Brower et al., 2001; Ehlers et al., 2010). These sleep disturbances can persist after months or even years of abstinence (Landolt and Gillin, 2001; Ford and Kamerow, 1989; Brower et al., 2001; Colrain et al., 2009; Landolt and Borbely, 2000; Williams and Rudell, 2008). Besides its disruptive effects on sleep, studies show that alcohol use, even in modest amounts, exacerbates snoring and sleep apnea in persons with OSA (Aldrich et al., 1993; Mamdani et al., 1989). Moreover, normal sleepers can develop snoring and OSA even after one drink (Dufour et al., 1992; Block et al., 1987).

Most studies examining the relationships between drinking and sleep problems are clinical and laboratory investigations. The analysis samples are small, and considerable heterogeneity exists in study design, sleep disturbances, and alcohol use measures. Surprisingly, we found only two studies that examine this relationship in large samples (Johnson and Breslau, 2001; Bruck and Astbury, 2012). Johnson and Breslau (2001) use data from the U.S. National Household Survey on Drug Abuse and find significant associations between sleep problems and substance use among adolescents. Adjusting for psychiatric problems reduces the magnitude of these associations, underscoring the importance of controlling for psychiatric problems. Bruck and Astbury (2012) use survey data to analyze potential predictors of ‘difficulty sleeping’ in a sample of young women. The authors find that psychiatric disorder symptoms are the strongest predictors of sleep difficulty. A few other factors, including binge drinking, are also found to have a significant impact on sleep difficulty.

Given the scarcity of studies employing large datasets, one of the most notable contributions to the current literature is our use of the National Longitudinal Study of Adolescent Health (Add Health), a large, nationally representative data set of young adults, to examine the relationship between alcohol consumption and sleep problems. Our study makes several other contributions to the existing literature. First, we analyze a range of alcohol use patterns (any, occasional, approaching weekly, and weekly or more frequent binge drinking) to shed light on a possible dose-response relationship between alcohol use and sleep disturbances, and to identify particularly harmful patterns of use. Second, as mentioned above, several studies find that part of the associations between sleep disturbances and substance use can be attributed to psychiatric problems (Johnson and Breslau, 2001; Park et al., 2010; Bruck and Astbury, 2012). Given the comorbidity between substance use and psychiatric disorders, we include in our regressions several indicators of psychiatric problems and disorders (i.e., past year psychological or emotional counseling, depression, post-traumatic stress disorder, and panic disorder diagnoses) to further our understanding of the relationships between

drinking, sleep problems, and mental health. Third, several personal characteristics, physical health conditions, and other substance use are potentially correlated with both sleep patterns and alcohol use. Ignoring these variables would lead to biased estimates of the relationships between drinking and sleep problems. The diversity of the Add Health data allows us to include a comprehensive set of confounding factors, thus avoiding the potential bias that would result from ignoring these variables or using a less comprehensive set of data. Finally, we test the robustness of our findings with several sensitivity analyses.

### 1.1 Conceptual Background

The reported associations between alcohol use and sleep problems can be explained, at least in part, by the pharmacologic effects of alcohol. This effect seems to be dose-related (Stein and Friedman, 2005). At low to moderate doses, alcohol can have a stimulating effect that might lead to problems falling asleep, usually during the first hour after its use (Stein and Friedman, 2005; Van Reen et al., 2011). At high doses, alcohol has a sedating effect (Petrucelli et al., 1994; Roehrs et al., 1989; Zwyghuizen-Doorenbos et al., 1988; Maclean and Cairns, 1982; Roehrs and Roth, 2001). Yet, the sedative effect of alcohol wears off quickly and is followed by sleep disruptions, especially during the second half of the night (Stein and Friedman, 2005; Vitiello, 2006; Van Reen et al., 2011; Roehrs and Roth, 2001; Landolt et al., 1996). During the first part of the sleep cycle, the body adjusts to the presence of alcohol in an effort to maintain a normal sleep pattern. Once alcohol has been eliminated from the body, however, certain physiological variables, such as REM-sleep patterns, change in the opposite direction of the body adjustments induced by alcohol. These changes result in sleep disruptions (Roehrs and Roth, 2001). Studies find that, after about a week of repeated nightly alcohol use, the sedative effect of alcohol diminishes, while its sleep disturbing effect remains (Stein and Friedman, 2005; Roehrs and Roth, 2001; Dufour et al., 1992; Rundell et al., 1972). Some studies report that tolerance to alcohol's sedative effect can develop after only three nights (Williams and Salamy, 1972).

The association between alcohol use and sleep problems, however, might be due to more than the pharmacologic effects of alcohol. Besides causing sleep problems, the use and misuse of alcohol could also be a reaction to sleep disturbances. Alcohol is commonly perceived to aid sleep, and many individuals drink alcohol to self-treat insomnia (Vinson et al., 2010; Vitiello, 2006; Johnson et al., 1998; Kaneita et al., 2007b; Ancoli-Israel and Roth, 1999). One study found that 67% of the respondents who reported both insomnia and alcohol use as a sleep aid felt that it was effective (Costa et al., 1996). Sleep problems might be early indicators of increased risk for substance use (Shibley et al., 2008). Moreover, sleep disturbances seem to be an important cause of relapse in alcohol dependent patients (Landolt and Gillin, 2001; Le Bon et al., 2003; Mahfoud et al., 2009; Ford and Kamerow, 1989).

Finally, it is possible that a common factor influences both alcohol consumption and sleep disturbances with no direct causality between the two. Several studies show that sleep disturbances, alcohol use, and psychiatric disorders often co-exist (Johnson and Breslau, 2001; Bruck and Astbury, 2012; Merikangas et al., 1996; Roberts et al., 1999; Park et al., 2010). Psychiatric disorders could lead to increased alcohol consumption, as well as to a higher likelihood of sleep problems. The comorbidity of substance use and psychiatric disorders is well known in the literature (Jane-Llopis and Matytsina, 2009). Some of the most common symptoms of anxiety and depression are sleep problems, such as difficulty falling asleep and staying asleep (Benca et al., 1992).

The current study further investigates the associations between alcohol use and sleep problems by using a large, nationally representative dataset of young adults. Various analyses attempt to disentangle the effects of binge drinking on sleep problems while controlling for several other important variables.

# 2. Methods

## 2.1. Sample

We use data from Add Health, a nationally representative survey of adolescents in grades 7 to 12 at Wave 1. Four waves of Add Health data are currently available. The first wave was initiated in 1994 and was, at that time, the largest, most comprehensive school-based survey of adolescents ever undertaken in the United States. The survey randomly selected 80 high schools stratified by region, school type (e.g., public, private), demographics, size, and level of urbanization from a sample frame of 26,666 schools throughout the country. Feeder schools that sent graduates to the 80 selected high schools were also identified. The final Wave 1 sample included a total of 134 middle and high schools.

Computer-assisted self-interviews were administered to 20,746 Wave 1 respondents in 1994. Wave 2 included only those Wave 1 respondents who were still attending school in 1995–1996 (71% of the Wave 1 sample). Wave 3 was collected in 2001 and 2002 and included 15,190 respondents (all original Wave 1 respondents who could be contacted and re-interviewed) between 18 and 26 years of age. A fourth in-home interview was conducted in 2007 and 2008 with 15,701 Wave 1 respondents. At the time of the interview, the Wave 4 participants were 24- to 32-years old. The analysis sample consists only of Wave 4 observations. Of those, we kept the observations that contained complete information for the sleep problems variables (N=14,089). We also considered incorporating data for sleep problems using information from the other three waves. Unfortunately, the sleep patterns questions in earlier waves were different and not as detailed as those from Wave 4.

## 2.2 Variables

**2.2.1 Sleep problems—**The Add Health survey asked how often respondents had trouble falling and staying asleep in the last four weeks. The respondents could choose from the following categories: never in the past four weeks, less than once a week, one or two times a week, three or four times a week, and five or more times a week. We use this information to create two dichotomous variables pertaining to problems falling asleep and problems staying asleep. We chose to collapse these response categories into dichotomous measures (i.e. presence or absence of the condition) because a large part of the sample (35% of males and 28% of females) reported no sleep problems during the past 4 weeks. Nevertheless, we also formed ordered categories from the sleep problem questions and, using the same set of explanatory variables, estimated these relationships with the ordered probit technique (see Sensitivity Analysis section that follows). In addition, the respondents were asked whether there were times when they snored or stopped breathing while sleeping. We use this information to form a dichotomous variable indicating snoring/sleep apnea during the past four weeks.

**2.2.2 Binge Drinking—**We construct several dichotomous measures of drinking during the past 12 months. First, we create a binary measure for any alcohol consumption during the past year to compare the sleep patterns of abstainers and drinkers. Second, to examine whether sleep problems are significantly associated with heavy consumption, we construct a dichotomous variable for any binge drinking during the past year. Binge drinking is defined as five or more drinks in a row for men and four or more drink in a row for women. The results for any binge drinking can be directly compared to the results for any drinking because both measures are binary. Finally, to explore whether more frequent binge drinking has a stronger association with sleep problems than less frequent binge drinking, we construct four binge-drinking categories and re-estimate all models with these binge-drinking dummies. Respondents could choose from seven binge-drinking categories: none, 1 or 2 days in the past 12 months, once a month or less, 2 or 3 days a month, 1 or 2 days a

week, 3 to 5 days a week, and every day or almost every day. To simplify the analysis and interpretation of results, we use these categories to construct four binge-drinking dummy variables: never binged, occasional binge drinker (1 or 2 days in the past 12 month to once a month or less), approaching weekly binge drinker (2 or 3 days a month), and weekly or more frequent binge drinker (1 or 2 days a week to every day or almost every day) in the past year. Sensitivity analyses incorporate other alcohol use measures. Specifically, we construct four categories for alcohol use and four categories for being drunk or very high on alcohol in the past year in the same way as our four binge-drinking dummy variables were constructed.

**2.2.3 Control Variables—**To separate the effects of alcohol use on sleep problems from the influence of other confounding factors, all models include a rich set of control variables. Several studies have found that age (Reyner et al., 1995; Ware et al., 2000; Ohayon et al., 2004), race/ethnicity (O'Connor et al., 2004; Mezick et al., 2008; Hall et al., 2009), and socioeconomic status (Breslau et al., 1997; Moore et al., 2002; Gellis et al., 2005; Mezick et al., 2008; Hall et al., 2009) are associated with individual sleep patterns and sleep problems. We therefore control for the following variables: age, race/ethnicity (dichotomous indicators for Hispanic, African-American, Asian, other race, with White as the reference group), years of schooling, current employment and marital status, number of persons in the household, labor market income in the past year, and being born outside the U.S.

Several studies also report that chronic medical conditions affect sleep (Grunstein et al., 1993; Schwartz et al., 1995; Shahar et al., 2001; Resnick et al., 2003; Pender and Pories, 2005; Vorona et al., 2005). Thus, we include a categorical measure for self-reported health status on a scale from 1 (excellent) to 5 (poor). Indicator variables for underweight, overweight, and obese (with normal weight as the reference group) were constructed. These dummy variables are based on height, weight, and waist circumference data collected by the Add Health interviewers from the study participants. The interviewers measured these characteristics according to standardized protocols. Binary variables were added for heart problems, diabetes, and high blood pressure.

Numerous studies have found that sleep patterns are highly correlated with mental health status and mental health disorders (Johnson and Breslau, 2001; Bruck and Astbury, 2012; Ford and Kamerow, 1989; Thase, 1998; Kaneita et al., 2007a). Thus, all models include dichotomous variables indicating lifetime diagnoses of depression, post-traumatic stress disorder, and panic disorder. Moreover, independent of these disorders, we include a dichotomous variable indicating whether the respondent received any psychological or emotional counseling in the past year for any type of mental health problem or disorder. Finally, because type of substance use can affect sleep patterns in differential ways (Johnson et al., 1998; Johnson and Breslau, 2001; Bootzin and Stevens, 2005), we include indicators for any marijuana use in the past 30 days, any illicit drug use other than marijuana in the past 30 days, and current smoking. The control variables mentioned above are entered collectively in all models.

## 2.3 Empirical approach

The core specification is as follows:

$$S^{*}=\beta_{A}A+BC'\beta_{BC}+X'\beta_{X}+E'\beta_{E}+\varepsilon \quad (1)$$

where $S^{*}$ is a latent variable indicating a particular sleep problem, $A$ is a measure of alcohol use, $BC'$ is a vector of behavioral characteristics (e.g., smoking, illicit drug use) excluding current alcohol use, $X'$ is a vector of socioeconomic variables and personal characteristics, $E'$ is a vector of physical and mental health endowment, and $\varepsilon$ is the error term. $\beta_{A}$, $\beta_{BC}$, $\beta_{X}$,

and $\beta_E$ are the coefficients to be estimated. Because $S^*$ is not observable, we define a dichotomous variable ($S = 1$ if $S^* > 0$ and $S = 0$ otherwise) and estimate the above relationship using the probit technique.

Several studies have shown that gender differences exist in sleep patterns and sleep problems (Hume et al., 2002; Ware et al., 2000; Young et al., 1996; Reyner et al., 1995; Redline et al., 1994; Rediehs et al., 1990). Moreover, males and females have different alcohol consumption patterns and experience different effects from drinking (Caetano, 1994; Hupkens et al., 1993; Robbins and Martin, 1993; Wilsnack et al., 2000). Thus, we follow convention in the substance use literature and estimate separate regressions for males and females.

The analysis is conducted using the Stata 11 statistical software package (Stata, 2009). The results of heretoskedasticity tests reject the null of homoskedasticity in most of the models. Hence, we estimate all models with robust standard errors. To account for the complex sample design of the Add Health dataset, we execute the Stata survey command (*svyset*). As suggested by the Add Health administrators, we assume that the schools were selected with replacement in the survey design. After eliminating the observations with missing sampling weights for Wave 4, these weights are employed to generate nationally representative estimates. We also use the post-stratification variable 'Region' and cluster at the school level. To conduct gender-specific analyses and obtain the correct standard errors, we employ the full dataset and use the 'subpopulation' option.

## 3. RESULTS

### 3.1. Descriptive statistics

Tables 1A (females) and 1B (males) present summary statistics for the variables used in the analysis. The means and standard deviations are computed using the Add Health sampling weights so that the data are representative of the U.S. young adult population. As mentioned earlier, we conduct separate analyses by gender.

Table 1A reports weighted variable means for 7,722 women, by binge drinking category. All control variables reveal highly significant differences in median values (Kruskal-Wallis (1952) rank-sum tests) across the binge drinking groups. Of particular interest are the statistically significant differences in median values for sleep problems measures across groups. The percentage of women who report having trouble falling asleep increases from about 52% for those without any binge drinking episodes to about 65% of those reporting weekly binge drinking. The same linear relationship can be observed for the percentage of women reporting trouble staying asleep. The prevalence increases from 56% for the women without binge drinking episodes to 68% for weekly binge drinkers. Moreover, the prevalence of snoring and sleep apnea problems increases from 41% of the women without binge drinking episodes to 49% of those reporting weekly binge drinking.

Table 1B reports weighted variable means and standard deviations for 6,781 men, by binge drinking category. Non-parametric Kruskal-Wallis (1952) rank-sum tests show statistically significant differences between binge drinking groups for most variables. While 45% of the men without any binge drinking episodes have trouble falling asleep, 55% of weekly binge drinkers report the same problem. The same linear relationship can be observed for the other two measures of sleep problems. The prevalence of men reporting trouble staying asleep increases from 48% for the men without binge drinking episodes to 56% for weekly binge drinkers. Moreover, while snoring and sleep apnea problems are reported by 51% of the men without binge drinking episodes, 61% of weekly binge drinkers report this problem.

Given the gender differences observed in the sleep problems and binge drinking variables, we also conduct rank-sum tests for significant differences in median values between males and females. The results of these tests reveal highly significant ($p<.01$) gender differences for all our sleep problems and binge drinking measures.

### 3.2. Regression analysis

Although we find significant bivariate differences in sleeping problems between the binge drinking categories, these differences could be attenuated by confounding factors. Tables 2A (women) and 2B (men) present the results of the multivariate probit regressions.

Overall, the estimates reveal that alcohol consumption is positively associated with trouble falling and staying asleep for both genders. Moreover, the results suggest a dose-response relationship as the estimated marginal effects increase with more frequent binge drinking. Most of the estimated marginal effects are statistically significant at the 1% or 5% levels.

The results for women indicate that drinking is associated with a 7.6 to 9.1 percentage point increase in the probability of having trouble falling asleep and an 8.4 to 9.1 percentage point increase in the likelihood of having trouble staying asleep. This is a substantial increase as, on average, about 56% (60%) of women reported problems falling (staying) asleep. The results for men tell a similar story, albeit a slightly smaller effect size. Drinking is associated with a 4.8 to 7.1 percentage point increase in the probability of having trouble falling asleep and a 5.5 to 7.4 percentage point increase in the likelihood of having trouble staying asleep for men.

Turning to our analysis of drinking patterns, snoring, and sleep apnea, the results reveal that drinking is positively associated with snoring and sleep apnea for men, but not for women. Specifically, drinking is associated with a 10.4 to 13.0 percentage point increase in the probability of reporting snoring/sleep apnea among men. The estimated marginal effects are statistically significant at the 1% level.

Supplementary Tables A (women) and B (men)[1] present the full estimation results. The estimated marginal effects for the control variables follow our expectations in almost all cases. Overall, the results for men are similar to those for women. Controlling for binge drinking, being African-American or born outside the U.S., having a larger number of persons in the household, and being in good physical health are all associated with decreases in the probability of having trouble falling or staying asleep. In contrast, respondents who are more educated, as well as those with a lifetime diagnosis of depression or panic disorders, are more likely to report sleep problems. A post-traumatic stress disorder diagnosis is not significantly correlated with sleep problems in women, but it is positive and statistically significant for men. Moreover, the results for psychiatric disorders suggest that depression is the strongest predictor of sleep disturbances for women, while post-traumatic stress is the strongest predictor among men. Snoring/sleep apnea is positively associated with age, being African-American, being overweight or obese, having diabetes, having high blood pressure, smoking, and having a diagnosis of depression. Being in excellent physical health has a negative effect on snoring/sleep apnea among women.

As shown above, gender differences are present among all the binge-drinking estimates. To assess whether these gender differences are statistically significant, we re-ran all our models with the full sample of respondents and, besides all the previous control variables, included a gender dummy and interaction terms between gender and each of our binge drinking variables. The results are presented in Supplementary Table C[2]. The estimated marginal

[1]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...

effects for the gender dummy show that, while men are less likely to have difficulty falling and staying asleep, they are more likely than women to snore and have sleep apnea. These results are statistically significant at the 1% level. Overall, the interaction terms are small in magnitude and lack statistical significance at conventional levels, probably due largely to multicollinearity among predictor variables.

### 3.3. Sensitivity analysis

We conduct several sensitivity analyses to check the robustness of our core findings. First, all specifications are re-estimated with linear probability models (i.e., OLS) instead of probit models to determine whether our findings are robust to functional form. The results are similar in sign and statistical significance relative to those produced by our core models.

Second, we re-estimate all models using two alternative sets of measures for alcohol use. Specifically, we construct four categories for alcohol use and four categories for being drunk or very high on alcohol in the past year. The results are consistent in sign and statistical significance with our core models using the binge drinking categories. As expected, the estimated marginal effects are smaller in magnitude for the drinking categories and slightly larger in magnitude for the “drunk” categories.

Third, we are concerned about the potential endogeneity of our binge drinking variables in the sleep problems regression models. It is possible that an unobserved variable (e.g., a personality trait) that is omitted from the model influences both the decision to binge and to engage in other risky behaviors that affect sleep patterns. Moreover, numerous studies have shown that, besides alcohol use causing sleep disturbances, some individuals with sleep problems might consume alcohol to self-medicate to promote sleep. In these instances, our analysis would be biased and causality cannot be inferred. The optimal method to address this endogeneity problem is instrumental variable (IV) estimation (Greene, 2008). Unfortunately, the Add Health dataset does not contain state or local identifiers, which results in our use of individual-level variables as instruments. We chose religiosity and alcohol availability in the home during adolescence (i.e., Wave 1). In first-stage probit regressions, both instruments are strong predictors of the probability of binge drinking ($p<.01$). Although the estimated marginal effects from recursive bivariate probit models are not estimated with precision (i.e., the estimates are not statistically significant at conventional levels), they are consistent in sign and magnitude with our core models. However, our individual-level instruments could be over identifying due to the fact that they are also potentially endogenous. Thus, we cautiously view the core results as associations rather than causal effects.

Fourth, to address potential reverse causality whereby sleep problems directly affect alcohol use, we restrict the sample to individuals who did not have a sleep problem in Wave 3. Unfortunately, the sleep-related questions asked in Wave 4 were not asked in Wave 3. Instead, we use the answers to the following question to proxy for a sleep problem in Wave 3: “In the past seven days, how often did you fall asleep when you should have been awake (for example, during class or at work)?” After dropping those individuals who reported one or more cases in Wave 3, the estimates are similar in sign, magnitude, and statistical significance to our core estimates.

Fifth, past binge drinking and a history of psychiatric problems are likely to affect current sleep problems as well as current binge drinking. Thus, we include two additional control variables in our models: a dichotomous variable indicating whether the respondent received

[2]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...

any psychological or emotional counseling in the past year at Wave 3 and a dichotomous variable indicating binge drinking in the past year at Wave 3. Selected estimation results from these augmented models are presented in Supplementary Tables D and E[3]. Overall, the key estimates change very little compared to our core results.

Finally, we used alternative (ordinal) measures for having trouble falling and staying asleep and estimate the relationships with ordered probit. Each variable includes integer values ranging from 1 to 5 for reporting sleep problems in the past four weeks: never, less than once a week, one or two times a week, three or four times a week, and five or more times a week. The results using these ordinal measures again show positive and statistically significant associations between binge drinking and sleep problems. Selected results of the ordered probit models are presented in Supplementary Tables F and G[4].

## 4. DISCUSSION

This study is, to the best of our knowledge, among the first to analyze the relationships between binge drinking and various sleep problems in a large and nationally representative sample of young adults in the U.S. By employing nationally representative data with corresponding sampling weights, the estimates are generalizable to young adults in the U.S. population. We find a strong and robust positive association between binge drinking and sleep problems even after controlling for numerous socio-demographic factors, psychiatric disorders, physical health, and other types of substance use. The estimated effects of binge drinking on sleep problems increase in magnitude with frequency of occurrence, which suggests a dose-response relationship. We also find statistically significant gender differences in the estimated relationship between drinking and sleep problems.

### 4.1. Limitations

While the previously mentioned findings are supported by our statistical analysis, there exist some limitations to our research. First, although our models include a rich set of control variables, it is still possible that other important variables that are associated both with sleep problems and alcohol use are omitted from the models either because they are not observable (e.g., individual characteristic) or because they are not available in the data set.

Second, another limitation pertains to the statistical assumptions underlying our empirical models. If binge drinking is strictly exogenous, our estimates represent unbiased causal effects of binge drinking on sleep problems. As mentioned above, however, it is possible that unobserved explanatory variables in the sleep problems equations (e.g., personal characteristics and traits) are correlated with our binge drinking variables. Moreover, alcohol consumption could be directly influenced by sleep problems, as individuals are trying to promote sleep through drinking (i.e., reverse causality). In the absence of panel data with identical measures across waves (the sleep problems questions were added in Wave 4 of the Add Health survey), it is very difficult to effectively address this issue. We attempt to implement an IV approach (see Sensitivity Analysis section above), but the estimated marginal effects were not statistically significant at conventional levels. Hence, we cautiously present our results as associations between binge drinking and sleep problems, rather than as causal effects per se. Nevertheless, the results of the IV estimation were consistent in sign and magnitude with the core results and the dose-response relationships identified in our core regressions are suggestive of a causal relationship. Further research with better data and measures is necessary to more rigorously investigate causal effects.

[3]Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...
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Third, as mentioned earlier, we recognize the importance of controlling for mental health status/disorders and mental health treatment as important factors influencing both sleep patterns and alcohol use. While we control for several mental health disorders, our dichotomous "psychological and emotional counseling" measure is very broad. It would have been preferable to separately include measures of mental health counseling for different psychiatric disorders. However, these data are not available in Add Health. Future research should carefully examine how specific psychiatric disorders and their treatment affect the relationships between alcohol misuse and sleep.

Finally, the manner in which the Add Health survey collected data poses as an additional limitation. Namely, Add Health respondents self-reported alcohol use. While the extent (if any) of misreporting in this area cannot be known with certainty, the literature on this topic suggests that self-reported substance use measures are generally reliable for use in statistical analyses (Darke, 1998; Del Boca & Darkes, 2003; Friesema et al., 2004; Lintonen et al., 2004).

### 4.2 Conclusion

In summary, we have established a significant, positive, and robust relationship between binge drinking and sleep problems. These findings could have important implications for policymakers and health care providers. Sleep problems and the misuse of alcohol have numerous negative consequences for society. Several clinical studies find that alcohol consumption prior to sleep is associated with severe daytime sleepiness and diminished reaction time and performance (Roehrs et al., 1994; Walsh et al., 1991; Ohayon et al., 1997). As a result, individuals who consume alcohol to promote sleep are more prone to traffic accidents, as well as to accidents at home and the workplace (Walsh et al., 1991). Besides contributing to accidents, sleep problems decrease quality of life, lead to workplace conflicts, decrease labor market productivity, and increase health care costs (Roth, 2005).

The total economic costs associated with insomnia are estimated at $92.5 to $107.5 billion annually (Stoller, 1994). In addition, individuals with OSA who consume alcohol are at increased risk for heart attacks and strokes (Bassetti and Aldrich, 1996). Given the substantial societal costs associated with the negative consequences caused by sleep problems, appropriate clinical and policy responses should be developed. This requires a clear understanding of the causal link between alcohol use and sleep disturbances. As alcohol use and sleep problems co-exist, it would be prudent to evaluate patients with diagnosed sleep problems for co-occurring alcohol use disorders. If alcohol misuse leads to sleep problems, effective alcohol abuse treatment programs may indirectly reduce the occurrence of sleep problems and thus have greater long-term economic benefits than previously estimated. Nevertheless, sleep disturbances should be monitored closely during recovery from alcohol abuse/dependency as they have been linked to relapse. Moreover, public policy tools such as alcohol taxation, purchasing age limits, and penalties for drunk driving that aim to reduce drinking may also reduce the negative consequences associated with the co-occurrence of sleep and drinking problems. If sleep disturbances are followed by alcohol misuse, patients treated for sleep disturbances using behavioral and pharmacological interventions should be monitored for problematic drinking. Finally, sleep problems might be an early indicator of increased risk for substance use among adolescents and young adults (Johnson and Breslau, 2001).

The strong association between binge drinking and sleep problems found in this study should be seen as a first step in understanding these relationships and should encourage much needed future research that explores the causal link between the two. Future studies should employ rigorous statistical methods to address the issue of endogeneity of alcohol use (i.e., IV estimation and/or fixed-effects models with longitudinal data) in order to

provide a deeper understanding of the causal mechanisms between alcohol use and sleep patterns.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## Table 1

**A. Mean Values for all Analysis Variables: Females**

| Variables | No Binge Drinking[1] (n=4,652) | Occasional Binge Drinking[2] (n=2,032) | Approaching Weekly Binge Drinking[3] (n=529) | Weekly Binge Drinking[4] (n=509) |
|---|---|---|---|---|
| *Sleep Problems, Past 4 Weeks* | | | | |
| Trouble Falling Asleep (%)[5] ** | 52.35 | 61.93 | 63.38 | 64.51 |
| Trouble Staying Asleep (%)[6] ** | 56.18 | 66.43 | 67.03 | 68.30 |
| Snoring/Sleep Apnea (%)[7] * | 40.84 | 39.92 | 36.70 | 49.33 |
| *Explanatory Variables* | | | | |
| Age (years) ** | 29.02 (1.81) | 28.76 (1.78) | 28.48 (1.69) | 28.58 (1.74) |
| White (%) ** | 59.81 | 77.62 | 78.55 | 78.54 |
| Hispanic (%) * | 13.75 | 9.88 | 8.61 | 9.82 |
| African-American (%) ** | 21.80 | 9.37 | 8.61 | 9.01 |
| American Indian (%) ** | 0.33 | 0.52 | 1.34 | 0.99 |
| Asian (%) | 3.41 | 2.32 | 2.63 | 1.56 |
| Other race (%) | 0.86 | 0.26 | 0.21 | 0.06 |
| Years of schooling ** | 14.01 (2.24) | 14.59 (2.07) | 14.53 (2.02) | 14.34 (2.12) |
| Currently employed (%) ** | 55.51 | 66.44 | 69.99 | 62.43 |
| Currently Married (%) ** | 45.45 | 37.58 | 30.62 | 22.29 |
| Household size ** | 2.59 (1.68) | 2.08 (1.51) | 1.87 (1.54) | 1.72 (1.49) |
| Labor market income, past year ** | 23,665 (29,298) | 31,672 (42,391) | 31,018 (24,825) | 28,728 (26,581) |
| Born outside the U.S. (%) ** | 5.15 | 3.17 | 1.67 | 1.70 |
| Fair or poor health (%)[8] ** | 11.15 | 7.99 | 5.68 | 8.39 |
| Good health (%)[8] | 35.03 | 33.02 | 30.35 | 33.84 |
| Very good or excellent health (%)[8] ** | 53.80 | 58.98 | 63.96 | 57.76 |
| Normal Weight (%)[9] ** | 30.51 | 38.30 | 45.59 | 42.35 |
| Underweight (%)[9] | 2.33 | 1.91 | 1.18 | 1.77 |
| Overweight (%)[9] | 24.26 | 26.15 | 26.38 | 22.97 |
| Obese (%)[9] ** | 42.88 | 33.62 | 26.84 | 32.89 |
| Heart problem (%) | 1.16 | 1.41 | 0.23 | 0.14 |
| Diabetes (%) ** | 3.26 | 2.71 | 1.17 | 1.08 |
| High blood pressure (%) * | 10.01 | 7.44 | 4.94 | 11.14 |

**A. Mean Values for all Analysis Variables: Females**

| Variables | No Binge Drinking[1] (n=4,652) | Occasional Binge Drinking[2] (n=2,032) | Approaching Weekly Binge Drinking[3] (n=529) | Weekly Binge Drinking[4] (n=509) |
|---|---|---|---|---|
| Any marijuana use, past 30 days (%) ** | 7.20 | 15.96 | 24.80 | 33.22 |
| Any other illicit drug use, past 30 days (%) ** | 2.97 | 5.02 | 7.78 | 19.99 |
| Current smoker (%) ** | 35.72 | 50.69 | 59.07 | 70.67 |
| Past year psychological or emotional counseling (%)[10] ** | 10.77 | 13.74 | 14.31 | 17.13 |
| Depression (%)[11] ** | 20.74 | 23.95 | 23.22 | 31.60 |
| Post-traumatic stress disorder (%)[11] | 3.67 | 3.08 | 4.11 | 5.73 |
| Panic disorder (%)[11] ** | 16.13 | 18.71 | 22.38 | 28.76 |

**B. Mean Values for all Analysis Variables: Males**

| Variables | No Binge Drinking[1] (n=3,071) | Occasional Binge Drinking[2] (n=1,903) | Approaching Weekly Binge Drinking[3] (n=699) | Weekly Binge Drinking[4] (n=1,108) |
|---|---|---|---|---|
| *Sleep Problems, Past 4 Weeks* | | | | |
| Trouble Falling Asleep (%)[5] ** | 45.08 | 50.54 | 51.57 | 54.62 |
| Trouble Staying Asleep (%)[6] ** | 48.33 | 55.17 | 51.60 | 56.37 |
| Snoring/Sleep Apnea (%)[7] ** | 50.96 | 62.53 | 59.59 | 61.23 |
| *Explanatory Variables* | | | | |
| Age (years) ** | 29.17 (1.86) | 28.99 (1.80) | 28.84 (1.82) | 28.94 (1.8) |
| White (%) ** | 59.94 | 73.70 | 75.52 | 75.03 |
| Hispanic (%) | 12.46 | 11.65 | 11.27 | 11.05 |
| African-American (%) ** | 23.51 | 9.02 | 9.43 | 10.07 |
| American Indian (%) | 0.37 | 0.58 | 0.39 | 1.32 |
| Asian (%) ** | 3.02 | 3.91 | 2.40 | 1.79 |
| Other race (%) | 0.67 | 1.11 | 0.96 | 0.70 |
| Years of schooling ** | 13.49 (2.20) | 14.18 (2.15) | 14.01 (2.07) | 13.45 (2.06) |
| Currently employed (%) ** | 64.61 | 71.63 | 72.04 | 72.82 |
| Currently Married (%) ** | 36.55 | 38.35 | 29.12 | 21.85 |
| Household size ** | 2.20 (1.62) | 1.95 (1.42) | 1.95 (1.45) | 1.81 (1.47) |
| Labor market income, past year ** | 33,018 (34,543) | 46,336 (48,577) | 42,482 (35,354) | 37,303 (28,988) |
| Born outside the U.S. ** | 4.57 | 5.52 | 3.81 | 2.13 |
| Fair or poor health (%)[8] * | 9.48 | 7.63 | 7.91 | 9.18 |
| Good health (%)[8] ** | 34.81 | 29.18 | 32.23 | 35.36 |

**B. Mean Values for all Analysis Variables: Males**

| Variables | No Binge Drinking[1] (n=3,071) | Occasional Binge Drinking[2] (n=1,903) | Approaching Weekly Binge Drinking[3] (n=699) | Weekly Binge Drinking[4] (n=1,108) |
|---|---|---|---|---|
| Very good or excellent health (%) [8] ** | 55.69 | 63.18 | 59.85 | 55.44 |
| Normal Weight (%)[9] * | 28.96 | 28.08 | 27.58 | 33.05 |
| Underweight (%)[9] | 0.80 | 0.87 | 0.26 | 1.05 |
| Overweight (%)[9] ** | 31.28 | 36.33 | 40.54 | 35.51 |
| Obese (%)[9] ** | 38.94 | 34.71 | 31.60 | 30.37 |
| Heart problem (%) | 0.84 | 0.50 | 0.52 | 0.81 |
| Diabetes (%) ** | 2.81 | 1.88 | 1.59 | 1.45 |
| High blood pressure (%) | 14.44 | 12.21 | 11.40 | 11.81 |
| Any marijuana use, past 30 days (%) ** | 13.38 | 20.09 | 29.47 | 39.58 |
| Any other illicit drug use, past 30 days (%) *** | 4.63 | 7.53 | 9.89 | 16.22 |
| Current smoker (%) | 42.00 | 50.39 | 57.38 | 68.81 |
| Past year psychological or emotional counseling (%) [10] | 8.67 | 8.32 | 6.65 | 7.02 |
| Depression (%)[11] | 10.89 | 9.33 | 9.57 | 10.96 |
| Post-traumatic stress disorder (%)[11] | 2.59 | 2.69 | 0.65 | 2.10 |
| Panic disorder (%)[11] * | 7.82 | 7.51 | 8.07 | 9.96 |

[1] A respondent who reported no episodes of binge drinking during the past 12 months.

[2] An occasional binge drinker is an individual who reported binge drinking 1 to 12 days during the past 12 months.

[3] An approaching weekly binge drinker is an individual who reported binge drinking 2 or 3 days a month during the past 12 months.

[4] A weekly or more frequent binge drinker is an individual who reported binge drinking 1 to 7 days a week during the past 12 months.

[5] Respondent had trouble falling asleep at least once during the past 4 weeks.

[6] Respondent had trouble staying asleep at least once during the past 4 weeks.

[7] Respondent reported snoring or sleep apnea during the past 4 weeks.

[8] Self-reported health status measure.

[9] Weight variables are based on data collected by the Add Health interviewers.

[10] Past year psychological or emotional counseling for any type of mental health problem or disorder

[11] Lifetime diagnoses of depression, post-traumatic stress disorder, and panic disorder.

** Statistically significant difference in variable medians across the binge drinking categories, $p<0.01$, Kruskal-Wallis equality of populations rank test.

* Statistically significant difference in variable medians across the binge drinking categories, $p<0.05$, Kruskal-Wallis equality of populations rank test.

## Table 2

**A. Selected Regression Results: Female**

| Alcohol Use Variables | Trouble Falling Asleep[1] | Trouble Staying Asleep[1] | Snoring/Sleep Apnea[1] |
|---|---|---|---|
| *N* | 7,503 | 7,507 | 7,491 |
| **Baseline means** | 0.559 | 0.604 | 0.403 |
| Current Drinker | 0.091** (0.019) | 0.091** (0.017) | 0.029 (0.019) |
| Current Binge Drinker | 0.076** (0.017) | 0.084** (0.019) | 0.008 (0.020) |
| Occasional Binge Drinking | 0.076** (0.019) | 0.081** (0.023) | 0.001 (0.022) |
| Approaching Weekly Binge Drinking | 0.088** (0.033) | 0.091** (0.035) | −0.018 (0.032) |
| Weekly Binge Drinking | 0.066 (0.043) | 0.084* (0.035) | 0.070 (0.040) |

**B. Selected Regression Results: Males**

| Alcohol Use Variables | Trouble Falling Asleep[1] | Trouble Staying Asleep[1] | Snoring/Sleep Apnea[1] |
|---|---|---|---|
| *N* | 6,584 | 6,584 | 6,584 |
| **Baseline means** | 0.487 | 0.517 | 0.579 |
| Current Drinker | 0.071** (0.024) | 0.055* (0.022) | 0.111** (0.021) |
| Current Binge Drinker | 0.056** (0.019) | 0.070** (0.020) | 0.125** (0.020) |
| Occasional Binge Drinking | 0.048* (0.023) | 0.073** (0.023) | 0.130** (0.023) |
| Approaching Weekly Binge Drinking | 0.060* (0.028) | 0.045 (0.030) | 0.104** (0.033) |
| Weekly Binge Drinking | 0.061* (0.026) | 0.074** (0.027) | 0.123** (0.029) |

Notes: Analyses used the Wave 4 sampling weights provided by Add Health and the strata variable Region. Robust standard errors clustered at school level are reported in parentheses. All specifications control for age, ethnicity, race, years of schooling, employment, marital status, household size, personal labor market income, born outside the U.S., health status indicators, BMI category, marijuana and other illicit drug use in the past 30 days, smoking status, ever diagnosed with a heart problem, diabetes, hypertension, depression, post-traumatic stress disorder, and panic disorder, and past year psychological or emotional counseling.

[1]Estimated with probit. Marginal effects are reported.

*Statistically significant, $p \leq 0.05$;

**Statistically significant, $p \leq 0.01$.