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## Adequate Sleep Moderates the Prospective Association between Alcohol Use and Consequences

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### Abstract

**Objective**—Inadequate sleep and heavy alcohol use have been associated with negative outcomes among college students; however, few studies have examined the interactive effects of sleep and drinking quantity in predicting alcohol-related consequences. This study aimed to determine if adequate sleep moderates the prospective association between weekly drinking quantity and consequences.

**Method**—College students ( $N = 568$ ) who were mandated to an alcohol prevention intervention reported drinks consumed per week, typical sleep quantity (calculated from sleep/wake times), and perceptions of sleep adequacy as part of a larger research trial. Assessments were completed at baseline and one-, three-, and five-month follow-ups.

**Results**—Higher baseline quantities of weekly drinking and inadequate sleep predicted alcohol-related consequences at baseline and one-month follow-up. Significant interactions emerged between baseline weekly drinking quantity and adequate sleep in the prediction of alcohol-related consequences at baseline, one-, three-, and five-month assessments. Simple slopes analyses revealed that weekly drinking quantity was positively associated with alcohol-related

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consequences for those reporting both adequate and inadequate sleep, but this association was consistently stronger among those who reported inadequate sleep.

**Conclusion**—Subjective evaluation of sleep adequacy moderates both the concurrent and prospective associations between weekly drinking quantity and consequences, such that heavy-drinking college students reporting inadequate sleep experience more consequences as a result of drinking. Research needs to examine the mechanism(s) by which inadequate sleep affects alcohol risk among young adults.

### Keywords

alcohol; drinking; college students; sleep; intervention

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## 1. Introduction

Excessive alcohol use places many college students at risk for academic difficulties, injury, or even death (Blanco et al., 2008; Hingson, Zha, & Weitzman, 2009; Johnston, O'Malley, Bachman, & Schulenberg, 2012). Although some college students consume alcohol without experiencing negative consequences (Barnett et al., 2014; Barnett, Merrill, Kahler, & Colby, 2015; Hingson, 2010), many students who drink alcohol report health concerns, including mental health problems, risky sexual behaviors, and weight concerns (Oswalt, Lederer, & Schrader, 2015). Research is needed to understand the behavioral patterns that increase risk of adverse alcohol consequences among young adults.

One potential risk factor for negative drinking-related outcomes is sleep. Poor sleep has been linked to greater alcohol misuse among adolescents (Wong, Robertson, & Dyson, 2015), college students (Kenney, LaBrie, Hummer, & Pham, 2012; Kenney, Lac, LaBrie, Hummer, & Pham, 2013), community samples (Weissman, Greenwald, Nino-Murcia, & Dement, 1997), and alcohol-dependent patients (Brower, Krentzman, & Robinson, 2011). College students, in particular, tend to report irregular and insufficient sleep (Gellis, Park, Stotsky, & Taylor, 2014; Tsai & Li, 2004), with 12 to 14 percent of students reporting clinically significant symptoms of a sleep disorder (Gellis et al., 2014; Petrov, Lichstein, & Baldwin, 2014) and as many as 60 percent reporting poor sleep quality (Kenney et al., 2012; Lund, Reider, Whiting, & Prichard, 2010).

Inadequate sleep may increase risk for alcohol-related consequences among young adults. One mechanism to explain this association involves the tendency for sleep deprivation to decrease inhibition (Anderson & Platten, 2011) and impair decision-making (Killgore, Balkin, & Wsensten, 2006; Schnyer, Zeithamova, & Williams, 2009). Consistent with this hypothesis, poor sleep has been linked to increased alcohol-related consequences among college students after accounting for demographic variables and psychiatric problems (Kenney et al., 2013). Moreover, self-reported global sleep quality has been shown to moderate the association between alcohol use and related consequences in cross-sectional research, such that heavy-drinking college students experiencing worse sleep quality reported a significantly greater number of alcohol-related problems (Kenney et al., 2012). When interpreting these data, however, it is not clear whether sleep difficulty precedes alcohol-related consequences or vice versa.

The current study extends previous research by determining if inadequate sleep moderates the association between weekly drinking quantity and alcohol-related consequences both concurrently and prospectively. Consistent with previous cross-sectional research (Kenney et al., 2012), we hypothesized that subjective reports of inadequate sleep would moderate the association between drinks consumed per week and alcohol-related consequences, such that individuals who drank more and reported inadequate sleep would report a greater number of alcohol-related consequences as a result of drinking. Because sleep difficulty has been identified a predictor of problematic alcohol use in longitudinal studies of adolescents (Wong et al., 2015), we also hypothesized that this moderating effect would endure over time.

## 2. Materials and Methods

### 2.1 Participants and Procedure

All study procedures were approved by the university's Institutional Review Board. Undergraduate students at a public, four-year, research university in the Northeast were recruited to participate in a larger research project (Carey et al., 2015). Students who violated campus alcohol policy and were mandated to participate in an alcohol education program by the Office of Community Standards between November 2011 and December 2013 were presented with the option of either participating in the research study (evaluating two brief interventions for alcohol use) or participating in the standard sanction. All students who consented to participate in the larger study were included in current analyses. Data for this study were collected at baseline, one-, three-, and five-month assessments. The baseline and one-month assessments were online surveys, which were completed in a private suite and facilitated by a research assistant; the two subsequent assessments were completed online from remote locations. The final sample consisted of 568 students (72% male, 84% White) with a mean age of 19.18 years ( $SD = 1.16$ ). Participants included freshmen (38%), sophomores (35%), juniors (18%), and seniors (9%).

### 2.2 Measures

**2.2.1 Descriptive information**—Participants provided information regarding their gender, age, height, weight, year in school, race/ethnicity, and fraternity/sorority ('Greek') affiliation. They also responded to four items estimating their typical bedtimes and waketimes on weekends and weekdays in the past month (e.g., "What time do you usually go to bed on week days?") (Wolfson & Carskadon, 1998). Self-reported sleep times were used to estimate total sleep time per night but did not account for time spent awake in bed (i.e., sleep onset latency or wake after sleep onset).

**2.2.2 Sleep Adequacy**—Participants indicated how often they experience adequate sleep by responding to the item, "How often do you think that you get enough sleep?" on a scale from 0 (*never*) to 4 (*always*) (Wolfson & Carskadon, 1998). Subjective perception of sleep adequacy, rather than total sleep time, was used in analyses to account for individual differences in sleep need (i.e., some individuals may wake feeling rested after seven hours of sleep, while others may need nine hours to achieve the same subjective experience of restfulness) (Blunden & Galland, 2014; Carskadon & Short, 2014).

**2.2.3 Alcohol use**—The Daily Drinking Questionnaire (DDQ) (Collins, Parks, & Marlatt, 1985) was used to assess alcohol use over the past month. The DDQ was used to calculate typical drinks per week. A standard drink was defined as 12 oz. of beer, 5 oz. of 12% table wine, 12 oz. of wine cooler, or 1.25 oz. of 80-proof liquor.

**2.2.4 Alcohol-related consequences**—The Brief Young Adult Alcohol Consequences Questionnaire (B-YAACQ) (Kahler, Strong, & Read, 2005) is a 24-item self-administered assessment of problems related to drinking; responses are dichotomous (*yes/no*) and refer to the past month. The B-YAACQ has demonstrated strong psychometric properties and is free of gender bias (Kahler et al., 2005). Example items include, “I have felt very sick to my stomach or thrown up after drinking,” and, “I have woken up in an unexpected place after heavy drinking.” Reliability in this sample was high ( $\alpha = .84$ ).

### 2.3 Data Screening & Analysis

Data were screened for missing values, outliers, and normality prior to analysis. No imputation procedures were used for missing values; therefore, *N*s vary across analyses. For count variables, we trimmed outliers above three times the interquartile range from the 75<sup>th</sup> percentile plus one unit (Tukey, 1977). After accounting for outliers in this way, skewness and kurtosis estimates were within the normal range (Kline, 2011).

Hierarchical multiple regression analyses were used to test the hypothesized interactions. All analyses were conducted in SAS 9.4, and separate analyses were performed for each of the four outcomes. Prior to conducting the regression analyses, predictor variables, drinks consumed per week, and sleep adequacy were mean centered to aid in interpretation of interactions. In all models, participants' gender (0 = female, 1 = male), age, ethnicity (0 = non-White, 1 = White), and Greek (fraternity/sorority) affiliation (0 = no, 1 = yes) were included as covariates.<sup>1</sup> When modeling one-, three-, and five-month alcohol-related consequences, baseline consequences score was added as a covariate. Moderation analyses were conducted in two steps. First, drinks per week and sleep adequacy were regressed onto alcohol-related consequences at baseline, one, three, and five months. Next, the interaction between drinks per week and sleep adequacy and their respective main effects were regressed on each alcohol-related problems outcome. When significant interactions emerged, tests of simple slopes were used to evaluate the association between drinks per week and alcohol-related consequences at high (+1 *SD*) and low (-1 *SD*) levels of adequate sleep (Cohen, Cohen, West, & Aiken, 2003).

## 3. Results

### 3.1 Descriptive Statistics

Correlations, means, and standard deviations for study variables are presented in Table 1. At baseline, participants reported having an average of 12.49 (*SD* = 9.25) standard drinks over

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<sup>1</sup>Results were unchanged when study condition from the parent trial (i.e., a brief motivational intervention with either normative feedback email boosters or health promotion email boosters) was included in the model. When controlling for average total sleep time at baseline, the moderating effect of sleep adequacy on the association between drinking and consequences was also largely maintained (all *p*s > .05).

2.42 ( $SD = 1.22$ ) days in a typical week and experiencing 5.44 ( $SD = 4.25$ ) alcohol-related consequences in the past month. The majority of participants reported ‘sometimes’ (38%) getting enough sleep, while smaller numbers of participants reported ‘never’ (2%), ‘rarely’ (18%), ‘usually’ (37%), or ‘always’ (5%) obtaining adequate amounts of sleep. These subjective reports corresponded with an average total sleep time of 8.27 hours of sleep per night ( $SD = 1.02$ ; range 4.8-11.0), not accounting for time spent awake in bed. Overall, 2% of participants reported less than 6 hours of sleep per night, 6% reported 6 to 6.9 hours, 27% reported 7 to 7.9 hours, 40% reported 8 to 8.9 hours, 20% reported 9 to 9.9 hours, and 5% reported 10 to 11 hours per night.

Zero-order correlations revealed significant positive associations between baseline drinks consumed per week and alcohol-related consequences at baseline, one month, three months, and five months. Though it was not significantly related to drinks per week at baseline, adequate sleep at baseline was negatively associated with alcohol-related consequences at baseline and one-month follow-up (see Table 1).

### 3.2 Main Effects

Complete data for all main effects and interactions are presented in Table 2. Greater baseline drinks per week (DPW) and lower baseline levels of adequate sleep predicted alcohol-related consequences at baseline [ $B_{DPW} = .23$ ,  $SE = .02$ ,  $t(536) = 12.34$ ,  $p < .001$ ;  $B_{\text{sleep}} = -0.87$ ,  $SE = .18$ ,  $t(536) = -4.70$ ,  $p < .001$ ] and one-month follow-up [ $B_{DPW} = .07$ ,  $SE = .02$ ,  $t(518) = 4.16$ ,  $p < .001$ ;  $B_{\text{sleep}} = -0.39$ ,  $SE = .16$ ,  $t(518) = -2.46$ ,  $p = .01$ ]. At three- and five-month follow-ups, drinks per week [ $B_{3\text{mo}} = 0.07$ ,  $SE = .02$ ,  $t(375) = 3.03$ ,  $p = .003$ ;  $B_{5\text{mo}} = 0.10$ ,  $SE = .03$ ,  $t(328) = 3.58$ ,  $p < .001$ ], but not sleep adequacy [ $B_{3\text{mo}} = -0.13$ ,  $SE = .21$ ,  $t(375) = -0.62$ ,  $p = .54$ ;  $B_{5\text{mo}} = -0.09$ ,  $SE = .24$ ,  $t(328) = -0.37$ ,  $p = .71$ ], predicted alcohol-related consequences.

### 3.3 Moderated Effects<sup>2</sup>

At baseline, there was a significant interaction between DPW and adequate sleep in the prediction of alcohol-related problems [ $B = -.05$ ,  $SE = .02$ ,  $t(535) = -2.59$ ,  $p = .01$ ]. Results of simple slopes analyses indicated that DPW was positively associated with alcohol-related consequences for those with both adequate ( $B = .19$ ,  $SE = .02$ ,  $p < .001$ ) and inadequate ( $B = .28$ ,  $SE = .03$ ,  $p < .001$ ) sleep. However, the association between drinking and alcohol-related consequences was stronger among those who reported inadequate sleep (see Figure 1). The interaction between DPW and adequate sleep remained a significant predictor of alcohol-related problems at one-month [ $B = -.03$ ,  $SE = .02$ ,  $t(517) = -2.02$ ,  $p = .04$ ], three-month [ $B = -.05$ ,  $SE = .02$ ,  $t(374) = -2.34$ ,  $p = .02$ ], and five-month follow-ups [ $B = -.05$ ,  $SE = .02$ ,  $t(327) = -2.00$ ,  $p < .05$ ], with simple slopes analyses revealing trends similar to those found cross-sectionally (see Figures 1-2).

<sup>2</sup>Total sleep time (averaged across weekday and weekend nights) did not significantly moderate the association between drinking and consequences at baseline [ $B = -.02$ ,  $SE = .02$ ,  $t(529) = -0.97$ ,  $p = .33$ ], one-month [ $B = -.01$ ,  $SE = .01$ ,  $t(512) = -0.73$ ,  $p = .47$ ], three-month [ $B = -.001$ ,  $SE = .02$ ,  $t(371) = -0.07$ ,  $p = .94$ ], or five-month follow-ups [ $B = -.04$ ,  $SE = .02$ ,  $t(326) = -1.62$ ,  $p = .11$ ].

## 4. Discussion

This study extends the previous literature by establishing prospective associations between alcohol use, adequate sleep, and subsequent drinking outcomes. The majority of participants reported 'sometimes' getting enough sleep each night. Consistent with previous research (Kenney et al., 2012), sleep adequacy and typical weekly drinking quantity were unrelated; however, sleep adequacy moderated the association between alcohol use and consequences, such that those reporting less adequate sleep experienced a greater number of alcohol-related consequences as a result of drinking. Moreover, this finding was maintained at one-, three-, and five-month follow-ups, indicating that insufficient sleep can have a long-lasting, albeit indirect, effect on alcohol use outcomes.

Given the lack of direct associations between typical weekly drinking quantity and subjective reports of adequate sleep, the precise manner by which sleep influences alcohol-related consequences remains unclear. Sleep deprivation has been associated with impaired integrative decision-making among young adults (Schnyer et al., 2009), in which case heavy-drinking college students who are not receiving adequate sleep may have difficulty implementing protective behaviors (e.g., pacing alcohol consumption, drinking water or eating between drinks, staying with a buddy) that might buffer the association between alcohol use and consequences. Alternatively, because sleep deprivation has been associated with impulsive responses to negative stimuli (Anderson & Platten, 2011) and weakened ability to inhibit aggression (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006), inadequate sleep may heighten risk for aggressive behaviors while drinking. Sleep disturbance has also been associated with decreased positive mood (Acheson, Richards, & de Wit, 2007; Jean-Louis, von Gizycki, Zizi, & Nunes, 1998; Lund et al., 2010) and may precede the onset of depression in adolescents and young adults (Lovato & Gradisar, 2014). Therefore, it is possible that inadequate sleep leads to changes in mood that lead to changes in motives for drinking (e.g., drinking to cope). There is preliminary evidence for this hypothesis, as drinking to cope has been associated with increased alcohol-related harm among those receiving inadequate sleep (Kenney, Paves, Grimaldi, & LaBrie, 2014). Thus, in the presence of inadequate sleep, alcohol intoxication may result in failures of self-regulation that may subsequently result in negative alcohol-related consequences.

The prevalence of chronically inadequate sleep among the mandated students in the current sample is disconcerting. Approximately 20 percent reported never or rarely obtaining enough sleep, and an additional 38 percent reported receiving adequate sleep only 'sometimes.' These findings are consistent with data that up to 50 percent of college students report daytime sleepiness (DeMartini & Fucito, 2014) and 12 to 13 percent report clinically significant symptoms of insomnia (Gellis et al., 2014). Interestingly, the average total sleep time reported by participants in the current study was higher than that reported in previous research (Lund et al., 2010); however, these estimates do not account for sleep onset latency or wake after sleep onset and, therefore, may overestimate actual sleep duration. Although college students tend to minimize the importance of mild sleep problems (Orzech, Salafsky, & Hamilton, 2011), chronically disrupted sleep may alter individuals' cognitive and emotional perceptions of, and therefore responses to, stressful life events

(Meerlo, Sgoifo, & Suchecki, 2008). Thus, efforts to enhance college students' sleep quality in service of better mental health may be warranted.

Our findings replicate a previous study showing that sleep difficulty moderates the associations between heavy alcohol use and consequences (Kenney et al., 2012) and demonstrate that this associations persists over time. These findings suggest that improving the adequacy of sleep among heavy-drinking college students may decrease their risk for negative alcohol consequences. The majority of college students are interested in receiving information about sleep difficulties (Wagner & Rhee, 2013), and sleep habits can be improved as a result of sleep education (Orzech et al., 2011); however, few published studies have examined the efficacy of sleep interventions for college students.

Several limitations of this study should be noted when interpreting results. First, data were collected as part of a larger trial examining the effects of a brief motivational intervention for college student drinking; therefore, only brief measures of sleep duration and adequacy were available for secondary data analysis. Because the current study replicated findings of a study that used a reliable and valid measure of global sleep quality (Kenney et al., 2012), however, it is unlikely that outcomes were spurious. Given the design of the current study, we cannot determine why inadequate sleep predicts alcohol-related consequences several months later. Although our findings mirror those obtained with adolescents (Wong et al., 2015), use of an event-level (or similarly detailed) methodology is needed to determine how sleep difficulty impacts subsequent alcohol use. Additional research examining the impact of alcohol use on sleep is also needed, as the nature of 'inadequate sleep' is ambiguous (e.g., insufficient sleep duration, inadequate slow-wave sleep). Similarly, although research is consistent in documenting decreases in REM sleep as a function of alcohol use, the impact of alcohol on sleep onset latency in late adolescents is mixed (Chan, Trinder, Andrewes, Colrain, & Nicholas, 2013; Ebrahim, Shapiro, Williams, & Fenwick, 2013; Van Reen, Jenni, & Carskadon, 2006; Van Reen, Rupp, Acebo, Seifer, & Carskadon, 2013). Given the effects of both alcohol use and daytime sleepiness on GPA (Singleton & Wolfson, 2009), research may also examine the synergistic effect of these factors on academic performance. Our data were also limited by the use of self-reported outcomes. However, self-reported estimates of both alcohol use (Leffingwell et al., 2013) and sleep patterns (Wolfson et al., 2003) correlate with more objective measures of these health behaviors among young adults. Finally, participants were recruited from one campus, were predominantly White underclassmen, and were mandated to participate in an alcohol education program. It is important to replicate these findings with more diverse and non-college-attending young adults.

#### 4.1 Conclusion

The results of this study suggest that the subjective experience of sleep adequacy helps to explain the association between alcohol use and alcohol-related consequences among college students, such that heavy-drinking individuals reporting inadequate sleep experience a greater number of consequences as a result of drinking. This effect persisted up to five months, indicating that insufficient sleep may have a relatively long-lasting, indirect effect on the likelihood of alcohol-related consequences. We encourage research that examines the

mechanism(s) by which insufficient sleep affects alcohol risk among young adults, as well as research evaluating the feasibility and efficacy of sleep interventions for college students.

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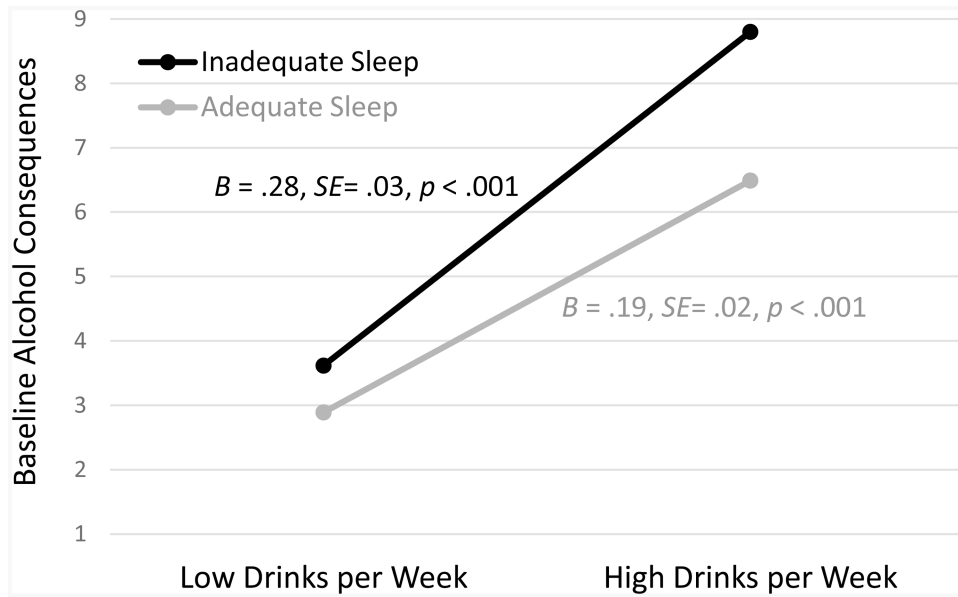


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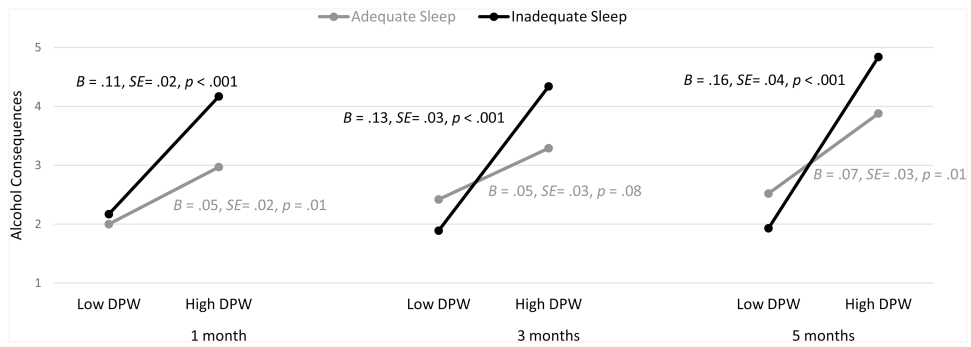
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### Highlights

- Sleep adequacy moderates the association between drinking quantity and consequences.
- Moderated effects exist concurrently and prospectively (up to five months).
- Research examining the mechanism(s) by which sleep affects alcohol risk are needed.
- Research regarding the efficacy of college sleep interventions is warranted.



**Figure 1.** Regression lines for the drinks per week by inadequate sleep interaction on alcohol-related consequences at baseline.



**Figure 2.** Regression lines for the drinks per week (DPW) by inadequate sleep interaction on alcohol-related consequences at one-, three-, and five-month follow-ups.

**Table 1**  
**Descriptive statistics and zero-order correlations among study variables (N = 568)**

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Male gender	--									
2. Age	-.05	--								
3. White race	-.08	.03	--							
4. Greek affiliation	-.04	.03	-.01	--						
5. Baseline drinks per week	-.28 <sup>***</sup>	.14 <sup>**</sup>	.20 <sup>***</sup>	.18 <sup>***</sup>	--					
6. Baseline sleep adequacy	-.10 <sup>*</sup>	.12 <sup>**</sup>	.14 <sup>**</sup>	-.01	.06	--				
7. Problems at baseline	.04	.04	.02	.09 <sup>*</sup>	.43 <sup>***</sup>	-.17 <sup>***</sup>	--			
8. Problems at 1 month	-.08	.01	.17 <sup>**</sup>	.11 <sup>*</sup>	.32 <sup>***</sup>	-.07 <sup>**</sup>	.40 <sup>***</sup>	--		
9. Problems at 3 months	-.06	.01	.03	.08	.32 <sup>***</sup>	-.06	.37 <sup>***</sup>	.50 <sup>***</sup>	--	
10. Problems at 5 months	-.02	.11	.08	.03	.28 <sup>***</sup>	-.18 <sup>**</sup>	.36 <sup>***</sup>	.57 <sup>***</sup>	.55 <sup>***</sup>	--
N or Mean	407	19.18	475	94	12.49	2.23	5.44	3.05	3.28	3.16
% or SD	71.7	1.16	83.6	16.5	9.25	0.88	4.25	3.88	4.04	4.20

Note.

\*  $p < .05$ ,

\*\*  $p < .01$ ,

\*\*\*  $p < .001$ .

Table 2

## Main effects and interactions for alcohol-related consequences

Baseline Alcohol-Related Consequences					
	<i>B</i>	<i>SE</i>	$\beta$	<i>t</i>	<i>p</i>
<i>Step 1: Main Effects</i>					
Age	-0.03	.14	-.01	-.18	.85
Male gender	1.59	.37	.17	4.35	<.001
White race	-0.48	.44	-.04	-1.08	.28
Greek affiliation	0.09	.44	.01	.20	.84
Drinks per week	0.23	.02	.50	12.34	<.001
Sleep adequacy	-0.87	.18	-.18	-4.70	<.001
<i>Step 2: Interactions</i>					
Sleep $\times$ Drinks per week	-0.05	.02	-.10	-2.59	.01
<b>1-Month Alcohol-Related Consequences</b>					
<i>Step 1: Main Effects</i>					
Age	-0.16	.12	-.05	-1.40	.16
Male gender	0.01	.31	.002	.04	.97
White race	0.42	.38	.04	1.10	.27
Greek affiliation	0.97	.36	.10	2.66	.008
Baseline alcohol consequences	0.25	.04	.30	6.78	<.001
Drinks per week	0.07	.02	.20	4.16	<.001
Sleep adequacy	-0.39	.16	-.10	-2.46	.01
<i>Step 2: Interactions</i>					
Sleep $\times$ Drinks per week	-0.03	.02	-.08	-2.02	.04
<b>3-Month Alcohol-Related Consequences</b>					
<i>Step 1: Main Effects</i>					
Age	-0.12	.16	-.04	-.81	.42
Male gender	-0.17	.40	-.02	-.43	.67
White race	1.28	.48	.12	2.65	.009

Baseline Alcohol-Related Consequences					
	<i>B</i>	<i>SE</i>	$\beta$	<i>t</i>	<i>p</i>
Greek affiliation	0.35	.48	.03	.72	.47
Baseline alcohol consequences	0.26	.05	.30	5.57	<.001
Drinks per week	0.07	.02	.18	3.03	.003
Sleep adequacy	-0.13	.21	-.03	-0.62	.54
<i>Step 2: Interactions</i>					
Sleep × Drinks per week	-0.05	.02	-.11	-2.34	.02
5-Month Alcohol-Related Consequences					
<i>Step 1: Main Effects</i>					
Age	-0.19	.18	-.06	-1.07	.28
Male gender	-0.22	.45	-.03	-.49	.62
White race	-0.28	.57	-.03	-.51	.61
Greek affiliation	0.26	.58	.02	.45	.65
Baseline alcohol consequences	0.24	.05	.26	4.42	<.001
Drinks per week	0.10	.03	.23	3.58	<.001
Sleep adequacy	-0.09	.24	-.02	-0.37	.71
<i>Step 2: Interactions</i>					
Sleep × Drinks per week	-0.05	.02	-.10	2.00	<.05