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ORIGINAL ARTICLE

Sleep, Alcohol and Cannabis Use in College Students With and Without Attention-Deficit/Hyperactivity Disorder

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ABSTRACT

Background: Relations among attention-deficit/hyperactivity disorder (ADHD), sleep, and substance-related negative consequences are largely unknown. In this cross-sectional study, we examined associations among ADHD diagnosis, sleep, and alcohol-related consequences. We also evaluated the independent and interactive effects of sleep and ADHD on alcohol-related negative consequences, above and beyond levels of alcohol use. *Methods:* College students who drink alcohol with ($n=51$) and without ($n=50$) ADHD completed an assessment that included a diagnostic interview assessing ADHD, and questionnaire measures of sleep quality, substance use, and associated consequences. Analyses utilized a series of hierarchical linear regression models and explored these aims for cannabis use in a subset of participants ($n=52$ participants that used cannabis). *Results:* College students who drink alcohol with ADHD reported significantly worse sleep quality and more alcohol-related consequences, relative to those without ADHD. When ADHD and sleep quality were included in the model, ADHD—but not sleep quality—was independently associated with alcohol consequences, but not cannabis consequences. There were no moderating effects of ADHD on the associations between sleep and substance-related consequences. *Conclusions*: Students who drank alcohol with ADHD may be particularly vulnerable to experiencing poor sleep and consequences from their substance use, compared to their heavy drinking peers without ADHD. Future, larger scale studies should consider longitudinal effects as well as underlying mechanisms of risk.

KEYWORDS
Alcohol; sleep; ADHD; college; cannabis

Introduction

Problem alcohol and cannabis use in college

College is a critical developmental period when students' autonomy increases as they test their independence, explore identities and interests, and form new peer groups, independently from caregivers and teachers. As students transition to college, many use alcohol and/or cannabis for the first time, often in a social context that is supportive of alcohol and drug use (Schulenberg et al., 2021). Indeed, 60% of college students reported drinking alcohol, 39% reported binge drinking, and 20% engaged in cannabis use over the past month (Welsh et al., 2019).

Unfortunately, alcohol use among college students has the potential to lead to negative consequences, including high-risk behaviors (e.g., aggression, suicide, sexual assault, property damage, impaired driving), academic problems, health consequences, less favorable career outcomes, and greater psychiatric impairment (Buckner et al., 2010; Weschler et al., 1994; Hingson et al., 2017; Jennison, 2004; Lipari & Jean-Francois, 2016; Welsh et al., 2019). In one study, college students endorsed at least one negative consequence on 33% of the days on which they consumed alcohol (Lee et al., 2020). This is particularly concerning given that negative consequences increase the risk of progression to alcohol use disorder (AUD; Debenham et al., 2019).

Like alcohol, frequent cannabis use is often associated with negative consequences for college students (Buckner et al., 2010; Kosterman et al., 2000). Among students who reported cannabis use in the past month, 90.8% reported one or more negative consequences (Pearson et al., 2017). Because college alcohol and cannabis use are prevalent and normalized in the college milieu yet can sometimes lead to significant negative consequences, identifying *which* college students are most vulnerable to alcohol and cannabis misuse is necessary to prioritize limited intervention resources.

ADHD, alcohol use, and cannabis use

The college transition may be particularly difficult for students with attention-deficit/hyperactivity disorder (ADHD), a neurodevelopmental disorder characterized by

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age-inappropriate symptoms of inattention and/or hyperactivity-impulsivity. These symptoms are thought to, in part, be due to impaired self-regulation (Brocki et al., 2017). College students with ADHD report worse academic abilities, psychosocial functioning, school engagement, substance use, and emotional difficulties than their peers without ADHD (DuPaul et al., 2017), and they are less likely to complete college (Weyandt & DuPaul, 2006). Importantly, alcohol and cannabis use may exacerbate the risk of such negative outcomes.

College students with ADHD show significantly higher rates of hazardous alcohol use (i.e., more likely to endorse drinking four or more times/week and binge drinking episodes) and higher rates of alcohol-related problems than their peers (Baker et al., 2012; Blase et al., 2009; Mochrie et al., 2020; Rooney et al., 2012). Students with ADHD also experience worse impairment as a result of their alcohol use, even when they retrospectively report consuming the same average quantity of alcohol as their peers (Rooney et al., 2012, 2015). Young adults with ADHD are also around three times more likely to have used cannabis in their lifetime and 1.5 times more likely to be diagnosed with cannabis use disorder (CUD) than individuals without ADHD (Lee et al., 2011). Together, these findings suggest that ADHD is a risk factor for negative consequences resulting from both alcohol and cannabis use.

Sleep quality, alcohol, and cannabis use, and ADHD

Sleep problems are ubiquitous among college students. In a large multi-site study examining 7,626 college students across six universities, 62% of participants met criteria for poor sleep (defined as scores >5 on the Pittsburgh sleep quality index; PSQI) (Becker et al., 2018). Furthermore, sleep and circadian disruption may alter reward functioning in emerging adult brains (increased risk-taking and reward sensitivity), which in turn can predict problem alcohol use, and those with higher levels of sleep problems report higher levels of substance use (Hasler et al., 2015; O'Brien & Mindell, 2005; Taylor & Bramoweth, 2010). These findings suggest that sleep problems may exacerbate the risk of substance misuse and are an important factor to consider when examining the substance-related consequences of a college sample engaging in heavy drinking.

Although alcohol use interferes with sleep homeostasis, it is also true that worse sleep can contribute to problem alcohol use and thus, theoretical models considering sleep as a predictor—rather than only an outcome—are needed (Thakkar et al., 2015). Research has shown that sleep patterns (weekend sleep delay/weekend oversleep) and duration predicted later alcohol use and that college students with worse overall sleep quality on the PSQI consumed more alcohol and were twice as likely to use alcohol as a sleep aid than their better sleeping peers (Lund et al., 2010; Orzech et al., 2011; Pasch et al., 2012). Sleep may also act as a buffer for alcohol-related negative consequences among college students (Kenney et al., 2012). These results suggest that poor sleep quality may act as a potential contributing factor to alcohol-related negative consequences, rather than simply an outcome of alcohol use.

Research has also linked sleep difficulties with cannabis use. In a study of over 12,000 U.S. high school students, shorter sleep duration was associated with more cannabis use (McKnight-Eily et al., 2011). Additionally, greater past-month cannabis use has been associated with sleep alterations, which include reduced slow wave sleep and rapid eye movement sleep (critical for deep, restorative sleep; Jacobus et al., 2009). Cannabis use appears to have a complicated relationship with sleep for college students, as previous literature has shown that using cannabis to assist with sleep is related to increased problem use and worse sleep efficiency (Drazdowski et al., 2021).

As students transition to college, there is a reduction in caregiver monitoring and structure around daily routines. This results in important routines—including sleeping—being disrupted and dysregulated, particularly for college students with ADHD, who have worse sleep quality, increased daytime dysfunction, and greater sleep disturbances compared to their college peers without ADHD (Becker et al., 2018). Thus, there are established associations between sleep and both alcohol and cannabis use, however, the association between sleep problems and alcohol- and cannabis-related negative consequences has yet to be explored in conjunction with ADHD.

Present study

This study is the first to examine if college students with heavy drinking and ADHD differ in their sleep quality from their peers engaging in heavy drinking without ADHD. Additionally, this is the first study to examine if the association between sleep quality and substance-related negative consequences is exacerbated for college students with ADHD. We hypothesized that college students with ADHD who drink would report worse overall sleep quality and more negative consequences from their alcohol or cannabis use, perhaps due to difficulties with self-regulation, which may exacerbate both sleep quality and their respective substance use consequences. We also predicted that worse sleep would be associated with more substance-related negative consequences and that this association would be stronger for those with ADHD (i.e., ADHD as a moderator). Additionally, we hypothesized that college students with ADHD who use cannabis would report more negative consequences from their cannabis use. Lastly, we predicted that sleep would be associated with cannabis-related negative consequences, such that worse sleep would predict more consequences and this association would be stronger for those with ADHD.

Methods

Participants

Participants were 101 (n = 49 females) full-time college students who drink alcohol with (n = 51) and without ADHD (n = 50) between the ages of 18 and 22 years old, recruited from a large university in the mid-Atlantic region of the United States. Recruitment consisted of campus listservs and flyers posted within the university counseling, accessibility, and disability support services and throughout campus.

Recruitment flyers included a brief study description, "to examine college drinking behavior and lifestyle choices." The cannabis-using subsample included 52 participants (n = 28 females) with (n = 34) and without ADHD (n = 18) who reported using cannabis in the past month. This subsample of the study was required to meet the same eligibility requirements as the full sample, and thus, they were also recruited for heavy alcohol use as well.

Students in the comparison group were eligible to participate if they: (1) had <3 current DSM-5 symptoms of ADHD; (2) reported no history of childhood ADHD; and (3) had never been prescribed ADHD medication. Participants in both groups were required to: (1) report drinking ≥3 days a week over the past two weeks, with no plans to change their alcohol use during the study period; (2) report at least 1 binge drinking episode in the last two weeks (defined by consuming 4+/5+ alcoholic drinks in 2 hours or less for females and males, respectively); (3) use disorder identification test (AUDIT; Saunders et al., 1993) score of ≥7 for males or ≥5 for females (DeMartini & Carey, 2012); (4) be a full-time undergraduate student at University of (omitted), and (5) between 18 and 22 years old. Exclusion criteria included current receipt of alcohol or drug treatment, or comorbidity requiring immediate treatment (e.g., bipolar disorder and schizophrenia) or imminent risk for harm to oneself or others.

Procedure

The Institutional Review Board at the University of (omitted) approved this study. This is a secondary analysis of a larger study evaluating the risk and protective correlates of college alcohol and drug use. Participants who met initial eligibility on the AUDIT (Alcohol Use Disorders Identification Test) were scheduled to speak with study personnel over the phone, where initial eligibility was confirmed and a baseline assessment was scheduled. To determine ADHD group membership, participants were administered a structured clinical interview assessing childhood and current DSM-V symptoms and completed questionnaires *via* Qualtrics (American Psychiatric Association, 2013). Excluded participants were compensated for their participation and provided relevant referrals ($n = 4$).[1]

Measures

ADHD measure

The adult ADHD Clinical Diagnostic Scale (ACDS; Kessler et al., 2010) is a semi-structured interview used to assess childhood and current ADHD symptoms for eligibility and group status (ADHD vs. non-ADHD). Interviews were administered by doctoral students who were trained to a reliability criterion ($k > 0.80$) and supervised by a licensed clinical psychologist. Approximately 67% of students ($n = 34$) in the ADHD group reported a prior diagnosis of ADHD, completed by either a medical or mental health provider.

Sleep measure

The Pittsburgh Sleep Quality Index (PSQI) includes nine items that assess: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. Higher scores reflected poorer sleep over the past month. Scores >5 indicate clinically significant sleep problems or "poor sleepers." Commonly used with college samples, the PSQI is internally consistent, reliable across four weeks, and is associated with other measures of sleep disturbance, including sleep diaries (Becker et al., 2014, 2018; Buysse et al., 1989; Carpenter & Andrykowski, 1998; Dietch et al., 2016).

Alcohol and cannabis use

The alcohol use disorder identification test (Saunders et al., 1993) is a 10-item questionnaire measuring alcohol consumption, dependence, and alcohol-related problems in the past year. A higher total AUDIT score indicates higher levels of engagement in risky alcohol use. The AUDIT has been shown to be both valid and reliable for college students (Kokotailo et al., 2004; Park et al., 2009).

The Daily Drinking Questionnaire (DDQ; Collins et al., 1985) asks participants how many drinks they consumed during each day of a typical week over the past month. This is a widely used and valid approach to assessing recent alcohol use (Kivlahan et al., 1990).

The Brief Young Adult Alcohol Consumption Questionnaire 30 Day (BYAACQ; Read et al., 2006) is a 24-item questionnaire that measures the number of alcohol-related negative consequences experienced over the past 30 days. The numerical responses (0 or 1) are totaled, with a larger number indicating more negative consequences. The B-YAACQ 30 Day is both reliable and valid and has been used in numerous college studies (Kahler et al., 2008), including college students with ADHD (e.g., Meinzer et al., 2021).

The Brief Marijuana Consequences Questionnaire (B-MACQ; Simons et al., 2012) is a 21-item questionnaire. The list of items asks participants to indicate "yes" or "no" for each consequence, and a sum score is calculated. The B-MACQ has been shown to be a valid and reliable measure in college student samples (Bravo et al., 2019).

Analytic overview

IBM SPSS Statistics Version 28.0 statistical software was used for all analyses (IBM Corp., 2019). Descriptive statistics are presented in Table 1. Bivariate correlations are presented in Table 3. All models included sex assigned at birth as a theoretically derived covariate, given documented sex assigned at birth differences in alcohol and cannabis use (Benton et al., 2004, 2006; Johnston et al., 1998). Additionally, in all models evaluating alcohol-related negative consequences, we included a covariate capturing typical drinks per week over the past month. Both typical drinks on a given week and the number of days using cannabis in the past month were included as covariates in models evaluating cannabis consequences to account for the fact that students

Table 1. Demographics table, full sample ($N = 101$).

Variable	ADHD	Non-ADHD controls	Total
Participant demographics	*N* (%)	*N* (%)	*N* (%)
Sex assigned at birth			
Female	22 (43.1)	27 (54.0)	49 (48.5)
Male	29 (56.9)	23 (46.0)	52 (51.5)
Racial/ethnic identification			
Asian	4 (7.8)	3 (6.0)	7 (6.9)
Black or African American	3 (5.9)	4 (8.0)	7 (6.9)
Hispanic/Latino	7 (13.7)	5 (10.0)	12 (11.9)
White (non-Hispanic/Latino)	36 (70.6)	33 (66.0)	69 (68.3)
>1 Race	1 (2.0)	5 (10.0)	6 (5.9)
Age			
18	6 (11.8)	5 (10.0)	11 (10.9)
19	14 (27.5)	6 (12.0)	20 (19.8)
20	16 (31.4)	11 (22.0)	27 (26.7)
21	12 (23.5)	24 (48.0)	36 (35.6)
22	3 (5.9)	4 (8.0)	7 (6.9)
Current alcohol use disorder	34 (66.7)	30 (60.0)	64 (63.4)
Previous ADHD diagnosis	34 (66.7)	N/A	N/A

ADHD: attention-deficit/hyperactivity disorder.

Table 2. Demographics table cannabis subsample ($N = 52$).

Variable	ADHD	Non-ADHD controls	Total
Participant demographics	*N* (%)	*N* (%)	*N* (%)
Sex assigned at birth			
Female*	15 (44.1)	13 (72.2)	28 (53.8)
Male*	19 (55.9)	5 (27.7)	24 (46.2)
Racial/ethnic identification			
Asian	4 (11.8)	2 (10.5)	6 (11.5)
Black or African American	1 (2.9)	2 (10.5)	3 (5.8)
Hispanic/Latino	6 (17.6)	1 (5.3)	7 (13.5)
White (non-Hispanic/Latino)	28 (82.4)	14 (73.7)	45 (86.5)
>1 Race	0 (0.0)	1 (5.3)	1 (1.9)
Age			
18	4 (11.8)	3 (15.8)	6 (11.5)
19	9 (26.5)	2 (10.5)	11 (21.2)
20	9 (26.5)	4 (21.1)	13 (25.0)
21	10 (29.4)	9 (47.4)	19 (36.5)
22	2 (5.9)	1 (5.3)	3 (5.8)
Current alcohol use disorder	23 (67.6)	13 (68.4)	35 (67.3)
Previous ADHD diagnosis	19 (55.9)	N/A	N/A

ADHD: attention-deficit/hyperactivity disorder.
*$p < .05$.

who use more alcohol and cannabis may have more negative consequences from their use. Therefore, the present study aims to examine the effects of ADHD and sleep on negative alcohol- and cannabis-related consequences beyond the amount of alcohol and cannabis consumed.

To evaluate associations among ADHD, overall sleep quality (PSQI), and alcohol-related negative consequences (BYAACQ), we conducted multiple linear regressions. To evaluate the interactive effects of sleep quality and ADHD on alcohol-related negative consequences, we used the PROCESS macro in SPSS (Model 3; Hayes, 2018). This same modeling approach was used for the exploratory aim of examining cannabis, using B-MACQ as the dependent variable.

Results

Prior to conducting analyses, the data were checked for assumptions and missingness. Only one data point among all study variables was identified as missing. Results from Little's MCAR test revealed the assumption that this data point was missing at random (χ^2 (1) = 0.685, $p = .408$). Assumptions for data independence, linearity, homoscedasticity, multicollinearity, and normally distributed residuals were all sufficiently met for analyses. No significant outliers were detected.

Descriptive statistics

Descriptive statistics and bivariate correlations for all study variables are shown in Table 1 (full sample) and Table 2 (cannabis using sample), respectively. Bivariate associations are also reported for the participants who used cannabis subsample ($n = 52$) in the shaded portion of Table 3.

ADHD group differences in sleep quality and alcohol- and cannabis-related consequences; associations between sleep quality and alcohol- and cannabis-related consequences

Full sample analyses

A multiple linear regression model revealed significant associations between ADHD and overall sleep quality: F (1,96) = 5.79, $p < .001$, R^2 =.153. Participants with ADHD also reported significantly worse overall sleep quality (M = 7.63) than those without ADHD (M = 5.37) (b = 2.35, $p < .001$). Both the ADHD group (M = 7.63 on the PSQI) and the non-ADHD group (M = 5.37 on the PSQI) were above the threshold for being considered clinically poor sleepers. Additionally, there was a significant association between ADHD and negative alcohol-related consequences, F(1,97) = 14.57, $p < .001$, R^2 =.331, such that participants with ADHD had significantly more alcohol-related negative consequences than those without ADHD (b = 2.37, $p < .01$). There were also significant associations between sleep quality and negative alcohol-related consequences (BYAACQ), F(1,96) = 13.99, $p < .001$, R^2 =.304. Worse sleep quality was significantly associated with more alcohol-related negative consequences (b = 0.366, $p < .01$).

Participants who used cannabis subsample analyses

In the subsample that used cannabis, there was a significant ADHD group difference in sleep quality after controlling for sex assigned at birth and number of days using cannabis, $F(1,48) = 3.05$, $p < .05$, $R^2 = .16$. Participants with ADHD also reported significantly worse overall sleep quality than those without ADHD, ($b = 2.39$, $p < .05$). Notably, students with ADHD were almost two times more likely to report using cannabis than those without ADHD in the present sample of students with heavy drinking (individuals with ADHD and cannabis use = 34; individuals without ADHD and cannabis use = 18). However, separate multiple linear regression models failed to find a significant association among ADHD and negative cannabis-related consequences in the subsample after controlling for sex assigned at birth and number of days using cannabis ($b = 1.11$, $p = .331$). Worse overall

Table 3. Descriptive statistics and bivariate correlation coefficients for overall sleep quality (PSQI), drinking (# of drinks in typical week), alcohol related negative consequences (BYAACQ), cannabis use (# of days using cannabis in past month), cannabis related negative consequences (BMCQ), ADHD, and sex assigned at birth.

Variable	1	2	3	4	5	6	7
1. Sleep quality		−.014	.260**	.089	.011	.370**	−.086
2. Drinking past month	−.039		.416**	.120	.200	.132	.418**
3. Alcohol consequences	.290*	.434**		.242*	.248	.292**	−.070
4. Cannabis use	−.041	.260	.143		.551**	.307**	.013
5. Cannabis consequences	.011	.200	.248	.551**		.280*	.362**
6. ADHD	.268	.159	.067	.217	.280*		.109
7. Sex	−0.207	.378**	−.099	.182	.362**	.285*	
Mean (SD): Control	5.37(2.3)	17.84(8.8)	6.44(4.1)	3.86(7.5)	2.28(3.6)	–	–
Range: control	1–10	4–51	0–17	0–27	0–14	–	–
Mean (SD): ADHD	7.63 (3.3)	20.57 (11.6)	9.12 (4.7)	9.88 (11)	4.94 (4.8)	–	–
Range: ADHD	1–16	6–60	2–22	0–30	0–17	–	–

Upper triangle represents full sample ($n = 101$) correlations and lower shaded triangle represents participants with cannabis use only ($N = 52$) sample correlations.
ADHD: attention-deficit/hyperactivity disorder.
*Correlation is significant at the .05 level (two-tailed).
**Correlation is significant at the .01 level (two-tailed).

sleep quality scores were not significantly associated with cannabis-related negative consequences ($b = 0.133$, $p = .425$).[2]

Independent and interactive effects of ADHD and sleep quality on negative alcohol-related consequences

See Table 4 for model results on independent and interactive associations. ADHD ($b = .177$, $p < .05$), but not sleep quality ($b = .256$, $p = .06$), was significantly associated with negative alcohol-related consequences, $F(2,95) = 11.98$, $p < .001$, $R^2 = .335$. No significant interaction between sleep quality and ADHD being associated with negative alcohol-related consequences was found, ($b = .37$, $p = .21$).[3]

Independent and interactive effects of ADHD and sleep quality on negative cannabis-related consequences

Neither ADHD ($b = .9$, $p = .46$) nor overall sleep quality ($b = .09$, $p = .62$) were significantly associated with negative cannabis-related consequences (Table 4). There was also no significant interaction of sleep quality and ADHD on negative cannabis-related consequences, ($b = -.31$, $p = .5$).

Discussion

Alcohol and cannabis use are prevalent among college students and can lead to substance use disorders. Therefore, a priority for researchers is identifying *which* college student engaging in heavy drinking are most vulnerable to experiencing negative consequences. Known risk factors for experiencing substance-related negative consequences include both poor sleep and ADHD, yet these risk factors have yet to be studied together in the same model or within heavy drinking samples. The present study represents an important step in examining ADHD, sleep quality, and substance-related negative consequences among students with and without ADHD, all engaging in high-risk alcohol use. Results indicated elevated risk for sleep and substance use consequences among students with ADHD, compared to their peers without ADHD.

Importantly, findings revealed that, on average, college students with heavy drinking and ADHD reported significantly worse sleep quality than college students engaging in heavy drinking without ADHD, even after controlling for sex assigned at birth and number of drinks consumed weekly. These results may suggest that ADHD is uniquely associated with poor sleep quality in college students engaging in drinking. It is possible that college students who drink with ADHD already experience worse sleep quality because of struggles with self-regulation around their sleep routines/behaviors, and alcohol use further exacerbates these self-regulation difficulties. These findings align

Table 4. Independent effects of ADHD and overall sleep quality (PSQI) on alcohol/cannabis related negative consequences (BYAACQ/BMCQ).

	Step and variable						
	df	*B*	*SE*	*T*	*p*	R^2	ΔR^2
Alcohol consequences	(2,95)						
Step 1:						.245	.245
Drinks in typical week		0.240	.043	5.560	<.001**		
Sex assigned at birth		−2.713	.890	−3.047	.003**		
Step 2:						.335	.090
Sleep quality		.256	.137	.188	.064		
ADHD		1.770	.839	2.104	.038*		
Step 3:	(5,94)					.350	.011
Sleep quality X ADHD		.370	.292	1.253	.213		
Cannabis consequences	(2,47)						
Step 1:						.378	.378
Sex assigned at birth		2.516	1.039	2.422	.019*		
Cannabis use days in past month		.225	.051	4.405	<.001**		
Step 2:						.393	.015
Sleep quality		.087	.178	.491	.626		
ADHD		.900	1.215	.741	.463		
Step 3:	(5,46)					.400	.010
Sleep quality X ADHD		−0.310	.453	−0.684	.498		

For the ease of visual presentation both hierarchical models are included in the above table, but models were each run separately during analyses. Cannabis consequences was run with the subsample ($N = 52$). Step 3 in each model was run using the PROCESS macro.
*$p < .05$.
**$p < .01$.

with prior work showing that college students with ADHD are at risk for experiencing sleep dysregulation and that alcohol use disrupts sleep—and when these factors were combined in the present study, poor sleep quality is exacerbated further (Becker et al., 2018; Pasch et al., 2012).

Analyses also revealed that, on average, college students with heavy drinking and ADHD reported significantly more alcohol-related negative consequences than college students engaging in heavy drinking without ADHD, despite no significant differences in the average number of drinks consumed between students with and without ADHD. These findings are consistent with prior work demonstrating that college students with ADHD report significantly more negative consequences from drinking, even though they do not report more alcohol consumption (Rooney et al., 2012). The current study also extends the literature by replicating this finding in a sample selected on the basis of heavy drinking. These findings may signal that there are unique underlying contextual correlates that individuals with heavy drinking and ADHD are engaging in that lead to more severe consequences from alcohol use. Indeed, knowing how much a person drinks only captures a slice of their decision-making, and future research is needed to clarify contextual correlates of risk.

Results of this study showed that ADHD, but not overall sleep quality, was significantly associated with negative alcohol-related consequences when included in the same model together, above and beyond sex assigned at birth and drinking quantity. It is possible sleep functioning on an aggregate level (i.e., past month sleep functioning) may not be a fine-grained enough measure to detect moderate independent associations between sleep and substance-use consequences in the same model with ADHD. Sleep functioning at the daily level likely would better capture this independent effect on alcohol-related consequences for drinking days. Regardless, having ADHD placed college students who drink alcohol at higher risk for experiencing negative alcohol-related consequences, and the mechanism behind this relation awaits further investigation using intensive daily longitudinal designs.

Outside of finding that ADHD was significantly associated with worse sleep quality in the cannabis-using subsample, no other significant ADHD group differences were found. Importantly, our cannabis using subsample ($N = 52$; ADHD = 34, non-ADHD = 18) included all substance users with relatively poor sleep quality and frequent negative cannabis-related consequences. Given the bivariate correlation between ADHD group and more cannabis-related consequences and no significant group differences in cannabis-related consequences after controlling for frequency of use, this may suggest those with ADHD are experiencing more consequences simply because of greater cannabis consumption. This pattern is different from alcohol-related consequences between groups finding, which is significant even when controlling for consumption. This preliminary examination of sleep, ADHD and cannabis-related consequences may set up future longitudinal research that can increase within-person power for analyses and explore in more detail *how* and *why* cannabis is being used for college students engaging in heavy drinking with and without ADHD. However, it is noteworthy that in the present sample, students with ADHD were almost two-times more likely to use cannabis.

Finally, contrary to expectations, our results demonstrated no significant moderating effects of ADHD on the relation between sleep and negative substance-related consequences. A priori power analysis confirmed the full sample size was sufficient to detect medium ($f^2 = .08$) effect sizes and thus, our analyses suggest the likelihood of a Type II error is low for a medium or larger effect size ($f^2 = .15$) with a power of .97. However, the sample size may have been underpowered to detect small effect sizes in an interaction and replication is therefore needed. It is also possible that a mediation model may better capture relations between ADHD, sleep, and substance-related negative consequences. For example, it is possible that ADHD predicts worse sleep quality, which in turn, predicts more negative consequences. Future longitudinal research is needed to examine if sleep is the mechanism that explains, at least partially, why students with ADHD experience more substance-related negative consequences.

There are some important limitations to consider. First, the present study was cross-sectional, and we could therefore not examine temporal associations among sleep, alcohol, and cannabis use. Because of the bidirectional nature of sleep and substance use, future longitudinal research can disentangle how sleep may act as both a predictor and outcome for college students with ADHD (Pasch et al., 2012). The sample was also relatively limited in terms of racial/ethnic diversity and included students enrolled in a 4-year institution. Future work should work to replicate these findings among a diverse population of students, including a range of gender identities, racial/ethnic identities, and socioeconomic and geographic status. The present study was also limited by the nature of some of the measures. It is possible that college students engaging in heavy drinking, especially those with ADHD, have poor insight into their sleeping habits and quality of sleep. Future research is needed that utilizes objective sleep tracking (e.g., actigraphy/polysomnography) and/or daily sleep diary that capture day-to-day sleep variability and that better correlate with objective sleep measures. Data collection occurred during the COVID-19 pandemic, which may have impacted sleep-wake regularity with virtual classes. Lastly, the present study did not account for other symptoms of psychopathology that could impact sleep (Becker et al., 2018), or characteristics of the environment that may contribute to both drinking risk and poor sleep (e.g., living with many other people who are engaging in heavy drinking).

Future research is also needed to continue to explore what is driving the association between ADHD and negative alcohol-related consequences. It is possible that students with ADHD are not drinking different amounts overall, but the way they drink or the context surrounding drinking contributes to the risk. For example, students with ADHD may not consume more alcohol during an average week than their peers without ADHD but could engage in alcohol use at riskier times (e.g., later into the night or the night before an exam) or use fewer protective behavioral strategies (e.g., drinking water before bed or between drinks, eating before drinking). Alternatively, students with ADHD are more likely to have impairments in academics, and alcohol use may further exacerbate these impairments by contributing to already-compounding procrastinated work and

studying (i.e., trying to cram assignments at the last minute while feeling hungover). Additionally, future work with this data to determine which specific consequences are being experienced across groups may provide more theoretical development for mechanistic models. Research that incorporates more fine-grained methodologies (e.g., daily diaries) to examine specific alcohol use behaviors is critical for examining the mechanisms behind the negative alcohol-related consequences students with heavy drinking and ADHD incur.

If follow-up research confirms sleep as a mechanism explaining why students with ADHD experience more negative alcohol-related consequences, sleep interventions could be a potentially effective way to triage care for college students with heavy drinking and ADHD. Recent research demonstrated the efficacy of a sleep intervention in young adults who drink and suggests that a focus on health behaviors like sleep may be a more palatable treatment target for young adults engaging in drinking (Fucito et al., 2017). Some existing sleep interventions have been adopted for use with adolescents with ADHD, and preliminary research shows promising results (Becker et al., 2022). However, these sleep interventions have yet to include participants engaging in heavy drinking or college students living independently of their parents. Thus, this high-risk population may be excluded in many current intervention contexts, where treatment is needed the most. Progress in other impairment areas like academics is unlikely to significantly improve before addressing these important health behaviors (i.e., sleep and substance use). In light of the present study findings, future work should also consider how these sleep interventions targeted for youth with ADHD can be extended to college students and whether such interventions reduce problematic substance use (Murphy et al., 2022). Research continuing to focus on understanding sleep in the context of both ADHD and substance use is critical, especially as the present study findings demonstrate that poor sleep is associated with more negative alcohol-related consequences.

The present study underscores the elevated risk college students with heavy drinking and ADHD face from alcohol use. On average, college students who drink with ADHD experience more alcohol-related negative consequences and worse sleep quality than their peers engaging in heavy drinking without ADHD. This study is the first to examine sleep quality and negative alcohol-and cannabis-related consequences in a college sample who drink alcohol with and without ADHD. Future research that incorporates longitudinal and daily diary methodologies can elucidate potential mechanisms behind the risk college students who drink with ADHD face and generate further areas for targeted interventions. The ability to examine causality and capture daily variability in sleep are critical next steps in elucidating mechanisms of risk that individuals with heavy drinking and ADHD face and pointing to targets for intervention.

Notes

1. Participants did not meet full diagnostic criteria for ADHD but had greater than three reported symptoms of ADHD to be included in the comparison group.
2. Analyses were conducted with and without covariates and no changes in results were found. Therefore, only the proposed analyses with covariates are reported.
3. Given the potential for stimulant medicine to interact with substances and increase negative consequences, stimulant medication use was examined about negative consequences. There was no significant relation between stimulant medication use and negative alcohol consequences (r = .110; p = .272, n = 101) or cannabis consequences (r = .144, p = .307, n = 52), thus, this was not added into the models as a covariate. Of participants with ADHD, approximately half (n = 26) self-reported currently being prescribed medication for ADHD.

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