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SCIENTIFIC INVESTIGATIONS

Daily associations between modifiable sleep behaviors and nighttime sleep among young adult drinkers with insomnia

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Study Objectives: Empirical evidence linking individual sleep hygiene practices to subsequent sleep parameters is limited, particularly at the daily level. This study compared the strength of daily, within-person associations between these modifiable sleep behaviors and nighttime sleep in young adult drinkers with insomnia.

Methods: Young adults (ages 18–30 years; n = 56) who met diagnostic criteria for insomnia and reported past-month binge drinking wore wrist actigraphy and completed online sleep diaries for 8.5 days (standard deviation = 2.3; 477 reports). Diaries assessed engagement in 11 sleep hygiene recommendations. Multilevel models tested daily associations between sleep behaviors and 3 outcomes: sleep quality, self-reported sleep efficiency, and actigraphy-measured sleep efficiency.

Results: Participants self-reported better sleep quality/efficiency on days that they slept in a comfortable environment, limited naps to 30 minutes, and maintained a consistent wake time. They self-reported worse sleep quality and efficiency on nights that they avoided alcohol use before bedtime. No sleep behaviors were significantly associated with actigraphy-measured sleep efficiency after correcting for inflation in type I error.

Conclusions: The sleep hygiene recommendations most strongly associated with sleep at the daily level were consistent with stimulus control. Creating a comfortable sleep environment also emerged as an important correlate of daily sleep. Heavy drinkers with insomnia may perceive better sleep if they drink before bedtime; however, this finding may be unique to this population.

Keywords: sleep hygiene, stimulus control, insomnia, sleep, alcohol

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Research to date has not examined associations between modifiable sleep behaviors and nighttime sleep at the within-person level. This study is the first to test these associations using both self-reported (sleep diary) and objective (actigraphy) reports.

Study Impact: Data provide empirical support for recommendations that young adult drinkers with insomnia prioritize a comfortable sleep environment, limit naps, and maintain a consistent wake time. In this sample of heavy drinkers, avoiding alcohol use before bedtime was associated with worse self-reported (but not objective) measures of sleep.

INTRODUCTION

Poor sleep health is characterized by self-reported dissatisfaction with sleep, inappropriate sleep timing, inadequate sleep duration, low sleep efficiency, and sustained daytime sleepiness.[1] The prevalence of poor sleep health ranges from 22%–60% in young adults.[2,3] Unfortunately, heavy drinking seems to exacerbate sleep problems. For instance, young adults who engage in binge drinking report a higher prevalence of problems falling asleep than those who do not binge drink (for women, 65% vs 52%; for men, 55% vs 45%).[4] In turn, poor sleep health has been associated with alcohol-related problems, resulting in a bidirectional cycle of poor sleep health and alcohol-related harm.[3–6] This trend has broad implications for public health in the United States, where 3 out of 4 people aged 18–34 years (∼79%) report alcohol use in the past year and 2 out of 5 (∼42%) report binge drinking in the past month.[7] Although causality cannot be established from these data, research has generally proposed a dose-response relationship between binge drinking and difficulty falling/staying asleep, and these associations persist after controlling for psychiatric symptoms (eg, posttraumatic stress, depression).[4] However, the majority of research has focused on aggregate (between-person) associations, and it is unclear how daily behaviors impact nighttime sleep at the within-person level, particularly in young adults who also have chronic insomnia. Given the tendency for individuals with insomnia to believe that alcohol helps with sleep[8]—and the economic burden associated with both sleep and alcohol use disorders[9,10]—research examining the impact of modifiable sleep behaviors is especially important in this population.

Sleep hygiene recommendations are behavioral and environmental instructions that aim to promote sleep onset, sleep maintenance, and sleep quality.[11] Although they tend to be less effective than multicomponent treatments[12,13] and are not recommended as a standalone treatment,[14] clinicians in nonspecialized

settings (eg, primary care) may provide sleep hygiene instructions for patients with sleep complaints.[14,15] Sleep hygiene recommendations generally include avoiding naps, getting adequate exposure to daylight, exercising regularly, creating a comfortable bedroom environment, establishing a relaxing bedtime routine, and avoiding foods and substances that may disrupt sleep before bedtime (eg, heavy meals, caffeine, nicotine, alcohol).[12,16] Maintaining a consistent sleep schedule (ie, regular bedtime/wake time) and managing stress are also sometimes included.[12,16]

Investigations regarding the impact of each individual sleep hygiene recommendation are limited and inconsistent and have not been investigated in a drinking population. In a sample of adults with insomnia (ages 20–60 years), 3 sleep hygiene practices were found to be associated with future insomnia risk: evening smoking/nicotine use, nighttime noise disturbance, and an irregular sleep schedule.[17] Improper sleep scheduling also emerged as a prospective correlate of insomnia risk among college students.[18] Cross-sectional studies are similar in finding intuitive, albeit somewhat varied, sleep hygiene correlates of good sleep. In 1 study of adults (ages 18–64 years), those with insomnia reported more alcohol use and smoking before bedtime, more naps, and more variable wake times than good sleepers.[19] In a sample of community-dwelling older adults (ages 60–96 years), poor sleepers only differed from good sleepers in weekly napping frequency, with poor sleepers reporting more frequent naps.[20] However, in at least 1 study of middle-aged women (ages 41–55 years), those with chronic insomnia reported drinking less caffeine and alcohol and less-variable bedtimes than those without insomnia.[21] Given the inconsistencies across these studies, the importance of various sleep hygiene recommendations seems unclear. However, all of these studies examined sleep behaviors at the between- (not within-) person level. That is to say, these studies could conclude that, on average, people who report more consistent sleep schedules seem to report better sleep than those with less consistent sleep schedules, but it is unclear whether any individual person reports significantly better/worse sleep after a day of variable sleep scheduling. No study has tested the daily, within-person associations between sleep hygiene practices and night time sleep. Such evaluations will inform clinical recommendations regarding the importance of various sleep hygiene recommendations at the individual level.

This study aimed to build on previous research by examining within-person associations between the use of modifiable sleep behaviors and subsequent nighttime sleep at the daily level. Data were collected in a sample of young adult drinkers who met the criteria for insomnia disorder. Self-reported sleep quality was identified as a primary sleep outcome because self-reported sleep disturbance is a defining characteristic of insomnia. Self-reported sleep efficiency was also identified as a primary outcome because it is used to determine treatment progress in cognitive behavioral therapy for insomnia (CBT-I)[22] and therefore may be regarded as 1 clinical indicator of sleep need. Actigraphy-based sleep efficiency was included to determine whether self-reported findings replicate using objective measures. In general, we hypothesized that engagement in recommended sleep behaviors would be positively associated with sleep outcomes. Given the dearth of research in this area, we did not make specific hypotheses about which sleep hygiene recommendations would be most effective.

METHODS

Participants and procedure

Data were derived from the baseline (not treatment or outcome) portion of a randomized controlled trial examining the efficacy of CBT-I among heavy-drinking young adults with insomnia.[23] Men and women between ages 18 and 30 years who reported drinking alcohol were recruited from a Midwestern college town in the United States (via flyers, university communications, Facebook, Instagram, and word of mouth) between August 2018 and June 2019. Interested participants completed a screening survey online from remote locations. Of the 143 participants who screened as eligible, 87 completed the baseline assessment. During the baseline assessment, participants provided informed consent and then completed a semi-structured clinical interview (the Mini-International Neuropsychiatric Interview for the *Diagnostic and Statistical Manual of Mental Disorders,* fifth edition and a semi-structured clinical interview of sleep disorders) with a trained graduate student. The sleep disorder interview was derived from the clinical interview that the senior author (who is board certified in behavioral sleep medicine) has used to diagnose sleep disorders in clinical settings. Participants were assessed for circadian rhythm disorders (including those related to shift work), sleep apnea, restless legs syndrome, periodic limb movement disorder, nonrapid eye movement sleep arousal disorders, nightmare disorder, rapid eye movement sleep behavior disorder, narcolepsy, and other medical disorders (eg, seizures, chronic medical illnesses). Participants then completed baseline measures and 7–14 consecutive days of online sleep diaries while wearing actigraphy. Participants were asked to complete daily diaries (~3-minute duration) online from remote locations every morning before noon. Anyone who had not completed their diary by noon received a reminder text or email from the research staff. Baseline diary reports were used to confirm the diagnosis of insomnia (ie, at least 3 nights of > 30 minutes sleep-onset latency or wake after sleep onset). The institutional review board approved all procedures.

Eligible participants (1) were ages 18–30 years, (2) reported at least 1 binge-drinking episode (defined as 4+ alcoholic drinks for women and 5+ for men on a single occasion) in the past 30 days, and (3) met *Diagnostic and Statistical Manual of Mental Disorders,* fifth edition and research diagnostic criteria for insomnia disorder (eg, > 30 minutes falling or staying asleep on 3+ nights per week for 3+ months, daytime impairment). Participants were excluded if they did not meet the criteria for insomnia (eg, symptoms did not meet the threshold for clinical diagnosis or sleep disturbance was better accounted for by a different sleep disorder; n = 9); denied binge drinking in the past 30 days at baseline (n = 4); had initiated a new sleep medication that might interfere with treatment effects in the past 6 weeks at baseline (n = 1); reported a history of mania or seizure disorder, for which the sleep restriction component of CBT-I is contraindicated (n = 2); or met criteria for a different sleep (n = 6) or psychiatric disorder (n = 9) requiring immediate clinical attention. No participants reported current treatment for insomnia or

alcohol use, which were also exclusion criteria. Fifty-six participants met all the inclusion criteria.

Measures

Covariates

Sex, current college enrollment, weekend vs weekday, insomnia severity, and drinking quantity were included as covariates in all models. Sex was included as a covariate based on sex differences in the prevalence of both insomnia[24] and heavy drinking.[25] Current college enrollment was included because binge and high-intensity drinking tends to be more common among college students than among noncollege-attending young adults,[26] and we controlled for the effect of weekends because young adults tend to drink[27] and sleep[28] more on weekends than on weekdays. Insomnia severity and drinking quantity were included to control for between-person differences in these variables at baseline.

To assess insomnia severity, participants completed the Insomnia Severity Index, which is a 7-item measure that has been validated in identifying insomnia in community and clinical samples.[29] Notably, the Mini-International Neuropsychiatric Interview has also shown reliability and validity in the diagnosis of mental health disorders among adults.[30]

Daily diary reports were used to assess drinking quantity. Specifically, participants reported the number of standard drinks of alcohol consumed each day. A standard drink was defined as 12 oz regular beer (∼5% alcohol), 8–9 oz malt liquor (∼7% alcohol), 5 oz table wine (∼12% alcohol), 3–4 oz fortified wine (∼17% alcohol), 2–3 oz liqueur (∼24% alcohol), 1.5 oz brandy (∼40% alcohol), and 1.5 oz 80-proof spirits (∼40% alcohol).

Sleep hygiene

Using daily diary reports, we coded participant engagement in 11 recommended sleep hygiene practices: (1) maintaining a consistent wake time, defined as within 30 minutes of one's median waketime; (2) limiting naps to 30 minutes; (3) doing something routine or relaxing in the 30 minutes before bedtime; (4) avoiding bright lights in the 30 minutes before bedtime; (5) engaging in 30+ minutes of moderate-intensity aerobic activity; (6) avoiding nicotine in the 2 hours before bedtime; (7) avoiding alcohol use in the 2 hours before bedtime; (8) avoiding caffeine after noon; (9) limiting caffeine to a maximum of 3 doses per day; (10) avoiding heavy meals within 2 hours of bedtime; and (11) going to bed in a comfortable sleep environment (rated as "good" or "very good"). These behaviors were coded as "sleep hygiene" practices because they are listed as such in various studies[12,16,17] and on the National Sleep Foundation's website (https://www.thensf.org). The wording of each diary item, response options, and criteria for coding each response as "engagement" (vs "nonengagement") is depicted in **Table 1**.

Sleep outcomes

In daily sleep diaries, participants estimated what time they got into bed, what time they attempted to fall asleep, how long it

Table 1—Daily diary sleep hygiene items, responses, and coding.

Recommendation		Survey Item	Response Options	Criteria for "Engagement"
1	Wake time	What time was your final awakening?	[open]	Within 30 minutes of median wake time
2	Naps	How long did you nap yesterday?	[open]	Duration ≤ 30 minutes
3	Bedtime routine	Did you do something routine or relaxing in the 30 minutes before bedtime yesterday?	Yes/no	Responded "yes"
4	Bright lights	Did you avoid bright light in the 30 minutes before bedtime yesterday?	Yes/no	Responded "yes"
5	Exercise	Did you engage in 30+ minutes of moderate-intensity aerobic activity yesterday?	Yes/no	Responded "yes"
6	Nicotine	At approximately what time did you finish your last cigarette yesterday?	[open]	2+ hours before bedtime
7	Alcohol	At approximately what time did you finish your last alcoholic drink yesterday?	[open]	2+ hours before bedtime
8	Caffeine timing	At approximately what time did you finish your last caffeinated drink yesterday?	[open]	Before 12 PM
9	Caffeine dose	How many doses of caffeine (1 oz espresso, 8 oz coffee, 12 oz soda) did you have yesterday?	[open]	Quantity ≤ 3
10	Heavy meals	Did you have a heavy meal within 2 hours of bedtime yesterday?	Yes/no	Responded "no"
11	Environment	Please rate the quality of last night's sleep environment (eg, temperature, darkness, noise level of the place where you slept)	0 (very poor) to 4 (very good)	Rated as "good" or "very good"

All sleep hygiene items were recoded as yes/no (coded 1 for "engagement" and 0 for "nonengagement") in analyses so that the effect size of each behavior could be compared.

took them to fall asleep, the total duration of nighttime awakenings, the time of their final awakening, and what time they got out of bed for the day. Nightly sleep efficiency was calculated by dividing the amount of time actually spent sleeping by the amount of time spent in bed. Participants also rated their self-reported sleep quality on a scale from 0 (very poor) to 4 (very good).

Participants also wore the Actiwatch Spectrum Plus (Philips Respironics, Murrysville, PA) during the baseline period to provide an objective measure of sleep efficiency. Actigraphy data were analyzed using medium sensitivity settings and 30-second epochs. Consistent with actigraphy scoring and interpretation guidelines,[31] self-reported start/end times for the sleep period were used when there was a discrepancy between self-reported and actigraphy-generated start/end times because actigraphy is less reliable in estimating these values for individuals with insomnia. The automated actigraphy algorithm was then used to estimate sleep efficiency.

Data screening and analysis

Participants completed an average of 8.5 diaries (standard deviation = 2.3; range = 1–15), resulting in 477 data points. Multilevel modeling was used to account for the repeated clustering of assessments within individuals. Data for self-report variables were missing on < 0.1% of data points. Actigraphy data were unavailable or uninterpretable for 7 participants; therefore, actigraphy analyses included 49 participants and 307 data points. All available data were utilized.

Analyses were conducted in IBM SPSS Statistics 26 (Armonk, NY). Unconditional models, which included only the random intercept and repeated effects of time, were conducted to determine the intraclass correlation coefficient for each outcome. Intraclass correlation coefficients indicated that 22% of the variance in sleep quality, 34% of variance in self-reported sleep efficiency, and 31% of variance in actigraphy sleep efficiency occurred between individuals (at level 2, denoted L2). The remaining variance occurred within individuals over time (at level 1, denoted L1).

Outcome models for sleep quality, self-reported sleep efficiency, and actigraphy sleep efficiency were conducted separately, and a Bonferroni adjustment was used to control for inflation in type I error ($\alpha = .05/3 = .017$). All models controlled for sex (0 = female, 1 = male), current college enrollment (0 = noncollege, 1 = college), weekend vs weekday (0 = Sunday to Thursday, 1 = Friday or Saturday), insomnia severity, daily drinking quantity at the within- and between-person levels (L1 and L2, respectively), and between-person (L2) indicators of each sleep behavior. Level 2 sleep behaviors were calculated as the percentage engagement with each sleep hygiene recommendation across the entire baseline period. Level 1 sleep behaviors were coded as 1 (engagement) or 0 (nonengagement) for each day. Continuous level 1 variables were centered by person means, and continuous level 2 variables were centered by grand means.[32] Intercepts were specified as random to allow for individual differences in the baseline levels of each outcome, and slopes were random to allow for within-person changes in variables over time. An autoregressive covariance structure (assuming smaller correlations with increased distance in time) was specified for repeated effects. Because all level 1 sleep behavior recommendations were coded on the same scale, regression coefficients could be used to estimate comparative effect sizes (ie, the amount of change in the outcome associated with engagement vs nonengagement).

RESULTS

Sample characteristics

Participants were 56 young adults with an average age of 22.4 years (standard deviation = 2.7; range = 18–30 years). Forty-two (75%) were women, and 41 (73%) were college students. Their racial/ethnic backgrounds were as follows: 46 (82%) non-Hispanic White, 5 (9%) multiracial, 3 (5%) Black, 1 (2%) Native American or Native Alaskan, and 2 (4%) Hispanic or Latino/a/x. The majority (n = 32; 57%) reported living in a house or apartment with friends or roommates; however, 8 (14%) lived alone, 8 (14%) lived with family or a spouse, 6 (11%) lived in a fraternity/sorority house, and 2 (4%) lived in a dormitory or other campus housing.

Participants reported an average insomnia severity score of 16.2 (standard deviation = 3.5; range = 10–26). Eighteen participants (32%) reported the use of sleep medication; specifically, melatonin (n = 12; 21%), diphenhydramine (n = 7; 13%), doxylamine (n = 2; 4%), Aleve PM (n = 1; 2%), and trazodone (n = 1; 2%). Two participants (4%) reported the use of multiple sleep medications. Baseline engagement with each sleep hygiene recommendation is depicted in **Table 2**.

In terms of substance use, participants reported an average of 12.6 standard drinks (standard deviation = 7.3; range = 4–48) in a typical week in the past month at baseline. Forty-seven participants (84%) met the criteria for alcohol use disorder, although the majority (n = 28; 60%) were mild and few (n = 5; 11%) were severe. Five participants (9%) also met the criteria for another substance use disorder (all cannabis use disorder), all of which were mild (n = 1; 20%) or moderate (n = 4; 80%). In baseline diary reports, 7 participants (13%) reported cigarette use, 19 (34%) reported cannabis use, 54 (96%) reported caffeine use, and 55 (98%) reported alcohol use. Seven participants (13%) reported the use of alcohol as a sleep aid and 9 (16%) reported the use of cannabis as a sleep aid. Finally, 23 participants (41%) endorsed at least moderate symptoms of depression on the Patient Health Questionnaire-9 (score 10+),[33] and 18 (32%) screened positive for moderate to severe symptoms of anxiety on the Generalized Anxiety Disorder-7 (score 10+).[34]

Outcome models

Inferential statistics for each outcome are presented in **Table 3**. Given the number of variables included in each model, level 2 sleep behaviors (percentage engagement with each sleep recommendation across the entire baseline period) were omitted from **Table 3**.

After controlling for all other modifiable sleep behaviors within the model, we found that 4 sleep behaviors were significantly associated with same-night sleep quality at the

Table 2—Percentage of baseline days on which participants engaged in sleep hygiene recommendations, in the full sample and by college enrollment (n = 56; 477 reports).

Recommendation	Full Sample (n = 56), M (SD)	College (n = 41), M (SD)	Noncollege (n = 15), M (SD)
1. Wake up within same 30-min window	48.7 (20.0)	47.7 (19.2)	51.4 (22.2)
2. Limit naps to 30 min	80.5 (21.7)	79.2 (23.0)	84.1 (18.0)
3. Engage in relaxing bedtime routine	42.1 (33.7)	39.1 (34.1)	50.4 (32.0)
4. Avoid bright light before bedtime	42.2 (34.4)	40.3 (34.4)	47.5 (35.1)
5. Engage in 30+ min aerobic activity*	21.6 (20.9)	21.3 (21.5)	22.2 (20.0)
6. Avoid nicotine within 2 h of bedtime	96.5 (12.9)	98.7 (4.9)	90.3 (23.0)
7. Avoid alcohol within 2 h of bedtime	80.8 (16.9)	81.5 (17.5)	78.9 (15.3)
8. Avoid caffeine after 12 PM	52.2 (33.4)	50.5 (31.0)	56.9 (40.0)
9. Limit caffeine to 3 (8 oz) doses	92.5 (16.8)	94.0 (15.4)	88.3 (20.1)
10. Avoid heavy meals within 2 h of bedtime	78.2 (19.3)	76.2 (21.2)	83.7 (11.9)
11. Create comfortable sleep environment	60.8 (33.3)	61.5 (33.0)	59.0 (35.0)

*Defined as at least moderate-intensity aerobic activity. M = mean. SD = standard deviation.

within-person level: participants reported significantly better sleep quality on nights that they slept in a comfortable environment (B = 0.50), limited naps (B = 0.32), and maintained a consistent wake time (B = 0.19). They also reported better sleep quality on weekends than on weekdays (B = 0.25). However, participants reported worse sleep quality on nights that they avoided alcohol use before bedtime (B = –0.39). At the between-person level, individuals reporting more-severe insomnia reported worse sleep quality than those reporting less-severe insomnia (B = –0.05). Participants reporting more-consistent wake times (B = –0.94; P = .017; 95% confidence interval, –1.71 to –0.17) and those who more consistently avoided nicotine use before bedtime (B = –1.59; P = .010; 95% confidence interval, –2.80 to –0.38) also tended to report worse sleep quality than those reporting less consistent wake times and those who used nicotine before bed, respectively. (The L2 [between-person] association between nicotine use at bedtime and sleep quality was no longer significant when controlling for smoking status [yes/no use of cigarettes]). After correcting for inflation in type I error, sleep quality did not differ significantly as a function of any other variable. As indicated by the regression coefficients, sleeping in a comfortable environment was the strongest within-person correlate of same-day sleep quality in this model.

Two sleep behaviors were significantly associated with self-reported sleep efficiency at the within-person level (see **Table 3**). Again, participants reported significantly better sleep efficiency on nights that they slept in a comfortable environment (B = 3.11) and worse self-reported sleep efficiency on nights that they avoided alcohol use before bedtime (B = –3.96). College students also self-reported better sleep efficiency than noncollege participants (B = 4.73). There were no other within- or between-person correlates of self-reported sleep efficiency.

No sleep behavior was significantly associated with actigraphy-measured sleep efficiency at the daily level (see **Table 3**). In contrast to self-reported models, college students reported worse actigraphy-measured sleep efficiency than participants not in college (B = –5.50).

DISCUSSION

We found empirical support for recommendations that young adult drinkers with insomnia prioritize a comfortable sleep environment, limit naps, and maintain a consistent wake time. Notably, these associations were found within persons (individuals experienced better sleep quality on nights that they slept in a comfortable environment) as opposed to between persons (if we had found that individuals who had comfortable sleep environments reported better sleep quality than individuals who had uncomfortable sleep environments). This extends the previous research on the importance of sleep hygiene recommendations,[17–21] which has been conducted primarily at the between-person level. Understanding of the day-level behaviors associated with better nighttime sleep is especially important in this population because young adults are unlikely to seek professional help[35] and their problems with sleep and alcohol use are likely to exacerbate one another.[3–6] Specifically, moderate to heavy doses of alcohol may impact sleep physiology,[6] and poor sleep health may compound the risk for alcohol-related harm.[5] Thus, identifying behavioral strategies that break this bidirectional cycle of sleep and alcohol problems may reduce the burden of these problems among young adults.

Somewhat surprisingly, sleeping in a comfortable environment was the strongest correlate of better sleep quality in this sample, and it was also associated with better self-reported sleep efficiency. We are unaware of previous studies examining "quality of your sleep environment" broadly as a predictor of subsequent sleep patterns. However, a number of studies suggest that light and noise disturbances at bedtime contribute to poor sleep health,[17,36,37] and a restful sleep environment is

Table 3—Associations between sleep behaviors and same-night sleep parameters (n = 56; 477 reports).

	Sleep Quality (Self-Report)			Sleep Efficiency (Self-Report)			Sleep Efficiency (Actigraphy)		
Parameter	**Estimate**	***P* Value**	**95% CI**	**Estimate**	***P* Value**	**95% CI**	**Estimate**	***P* Value**	**95% CI**
Intercept	1.62	< .001	0.77–2.48	86.83	< .001	77.27–96.39	81.70	< .001	67.48–95.92
L2 sex (male coded 1)	–0.25	.08	–0.54 to 0.03	0.66	.68	–2.52 to 3.85	–3.28	.14	–7.64 to 1.07
L2 college (student coded 1)	0.09	.57	–0.21 to 0.38	**4.65**	**.006**	**1.40–8.04**	**–5.50**	**.008**	**–9.50 to –1.49**
L2 drinking quantity (GMC)	–0.08	.28	–0.22 to 0.06	0.44	.58	–1.13 to 2.01	0.33	.75	–1.74 to 2.40
L2 insomnia severity (GMC)	**–0.05**	**.008**	**–0.08 to –0.01**	–0.38	.07	–0.78 to 0.02	–0.39	.14	–0.91 to 0.13
L2 SB variables omitted									
L1 drinking quantity (PMC)	–0.03	.13	–0.06 to 0.01	0.24	.21	–0.13 to 0.61	0.10	0.65	–0.34 to 0.55
L1 weekend (yes coded 1)	**0.25**	**.006**	**0.07–0.44**	0.95	.35	–1.06 to 2.95	1.44	.25	–1.04 to 3.91
SB1: consistent wake time	**0.19**	**.017**	**0.04–0.35**	–0.33	.72	–2.12 to 1.46	–2.24	.05	–4.48 to –0.001
SB2: limit naps	**0.32**	**.005**	**0.10–0.54**	2.22	.08	–0.28 to 4.72	1.36	.41	–1.87 to 4.59
SB3: bedtime routine	0.17	.11	–0.04 to 0.38	0.99	.41	–1.36 to 3.34	2.31	.13	–0.67 to 5.30
SB4: avoid bright light		.25	–0.08 to 0.33	0.56	.64	–1.78 to 2.91	–0.21	.88	–3.09 to 2.66
SB5: exercise	0.07	.49	–0.13 to 0.28	0.02	.99	–2.29 to 2.32	–1.96	.16	–4.71 to 0.78
SB6: avoid nicotine	0.18	.59	–0.48 to 0.84	–0.72	.85	–8.12 to 6.68	–6.27	.32	–18.64 to 6.10
SB7: avoid alcohol	**–0.39**	**.001**	**–0.63 to –0.15**	**–3.96**	**.004**	**–6.63 to –1.28**	–0.39	.82	–3.85 to 3.06
SB8: no caffeine after 12 pm	0.01	.95	–0.19 to 0.20	–2.07	.07	–4.31 to 0.16	–0.60	.68	–3.44 to 2.23
SB9: < 3 doses of caffeine	–0.37	.07	–0.76 to 0.02	–1.98	.39	–6.49 to 2.54	5.70	.03	0.51–10.89
SB10: avoid heavy meals	–0.17	.09	–0.36 to 0.03	–0.30	.79	–2.52 to 1.93	1.72	.23	–1.07 to 4.52
SB11: sleep environment	**0.50**	**< .001**	**0.30–0.70**	**3.11**	**.008**	**0.82–5.41**	–1.30	.35	–4.02 to 1.42

Bold variables are considered significant ($P \leq .017$). All sleep hygiene variables were coded as 1 (engagement) or 0 (nonengagement). CI = 95% confidence interval, GMC = grand-mean centered, L1 = level 1 (daily within-person) effects, L2 = level 2 (between-person) effects, PMC = person-mean centered, SB = sleep behavior at level 1.

ranked among the 3 most important sleep hygiene practices by young adults in college.[38] Although it may not always be possible for individuals to change their sleep environment, at least 1 study seems to indicate that rearranging the bedroom may be effective for socioeconomically disadvantaged women who are new parents.[39] Thus, in clinical settings, a discussion of the sleep environment and what (if anything) individuals can do to make that environment more comfortable may be warranted.

Limiting naps and maintaining a consistent wake time were also associated with better self-reported sleep at the daily level. Interestingly, both of these behaviors overlap with stimulus control therapy. Stimulus control instructions promote a conditioned response that associates the bed with sleepiness. As a complete treatment, stimulus control involves going to bed only when sleepy, using the bed and bedroom only for sleep (and sex), getting out of bed during extended nighttime awakenings, waking up at the same time every day, and avoiding daytime naps. It is a standard part of CBT-I and has shown efficacy both within the context of multicomponent treatments and as a standalone therapy.[40–42] Our findings provide additional support for stimulus control instructions—specifically, those that maintain sleep drive and strengthen one's circadian rhythm.[43] Avoiding naps and prioritizing consistent wake times may also be helpful for individuals who cannot tolerate the stimulus control instruction to leave bed during nighttime awakenings.

In contrast to the generally positive associations between engagement with sleep recommendations and sleep outcomes noted above, we found a negative within-person association between avoiding alcohol before bedtime and self-reported (but not objective) sleep parameters that night. This finding runs counter to a number of studies documenting negative within-person associations between alcohol use and self-reported sleep parameters in samples constituting a broader range of healthy young adult drinkers and nondrinkers.[44–47] However, at least 1 other study of young adult drinkers with sleep complaints failed to find a negative within-person association between alcohol use and sleep quality.[48] Moreover, at the within-person level, moderate to heavy doses of alcohol before bedtime have been linked to decreased sleep onset in some studies[49–51] and to improved slow-wave sleep (in the first half of the night) among individuals with insomnia.[52] Thus, this particular finding may be unique to relatively heavy drinkers with insomnia. Alternatively, participants in this sample also reported going to bed later on drinking vs nondrinking nights;[53] as such, we speculate that the association between drinking and improved self-reported sleep results in part from increases in sleep drive that promote sleep onset and quality.[43] However, this finding implies that young adult drinkers with insomnia may perceive beneficial effects of alcohol, even if drinking before bedtime is not associated with objective measures of improved sleep. Thus, providers likely need to be attentive to patients' perceptions of alcohol's impact on sleep when working with this population. Notably, the positive association between alcohol use and sleep reported here occurred at the within-person level (ie, participants reported better sleep on nights that they drank before bedtime than they did on nights that they abstained before bedtime). Thus, this finding does not contradict or discredit previous between-person findings that young adults who binge drink tend to report worse sleep than those who do not binge drink.[4]

In contrast to hypotheses, no sleep behaviors were associated with sleep efficiency measured using actigraphy. The direction of the association between college enrollment and sleep efficiency also flipped in self-reported vs actigraphy models (ie, college students showed better sleep efficiency than noncollege participants in self-reported models but worse sleep efficiency in actigraphy models). Both findings are consistent with previous research indicating that daily diaries (self-reported measures) and actigraphy (objective measures) capture different dimensions of the sleep experience.[54]

Although within- (not between-) person associations were the primary aim and focus of this manuscript, we also found that participants reporting more consistent wake times tended to report worse sleep quality than those reporting less consistent wake times. We did not include a systematic assessment of participants' daytime schedules in this study, so it is not clear why this between-person difference may have occurred. However, it is possible that participants who consistently had to get up early for work or other obligations rated their sleep quality as lower than individuals who did not have these obligations, even though they perceived their sleep as being better on mornings that they woke up close to their normal time (as opposed to a different time). Participants who consistently avoided nicotine before bedtime also reported worse sleep quality than those who used nicotine before bed, but this association was no longer significant after controlling for differences in sleep quality between smokers and nonsmokers. Therefore, this particular finding is likely a function of the sample, and associations between nicotine use and sleep quality may differ in populations of smokers.

This study also failed to find a significant association between a number of sleep hygiene behaviors and nighttime sleep. Specifically, after controlling for all other sleep hygiene behaviors, we did not find statistically significant support for recommendations to implement a bedtime routine; engage in moderate-intensity aerobic activity; avoid bright light, nicotine, and heavy meals before bedtime; or avoid/limit caffeine. Although it is possible that these recommendations are inherently less effective than others, it is also possible (as we have noted) that certain sleep hygiene recommendations are more or less important in certain populations. For example, engaging in aerobic activity may have a different impact on sleep among individuals who tend to be sedentary than it does among those who are typically more active. Previous studies have found that nicotine use before bedtime[17] and caffeine use in the late afternoon[36] are negatively associated with sleep; thus, these recommendations, in particular, warrant continued attention.

Clinical implications

Although sleep hygiene therapies tend to be less effective than other cognitive behavioral treatments,[12,13] clinicians in nonspecialized settings may rely on sleep hygiene recommendations for patients presenting with sleep complaints.[14] For instance, 3 out of 4 primary care providers at a Veterans Affairs health care organization (77%) utilized general sleep hygiene

recommendations in their practice, and 84% reported recommending that patients avoid stimulants before bedtime.[15] However, 43% of these providers were unsure whether CBT-I was available at their facility,[15] indicating that patients with insomnia are unlikely to receive appropriate referrals. As we have noted, multicomponent sleep hygiene education interventions do tend to produce significant posttreatment improvements in self-reported sleep measures;[12] however, this finding is not typically indicated in comparison to any form of control condition.[14] Sleep hygiene alone is unlikely to be effective in treating chronic insomnia and should be used in conjunction with other evidence-based therapies, such as CBT-I.[14,55] However, in the absence of these options, the data support recommendations for young adult drinkers with insomnia to prioritize a comfortable sleep environment, limit naps, and maintain a consistent wake time.

Limitations

Findings should be considered in light of the limitations of this study. First, the overall sample was relatively small, which may raise concerns regarding power. However, significant associations were identified. Moreover, in multilevel models, sample sizes of 30 or more tend to have a minimal impact on estimated within-person (L1) fixed effects and standard errors.[56] Second, participants were young adult drinkers who met the diagnostic criteria for insomnia. Although the inclusion of individuals with insomnia may be considered a strength because the effectiveness of sleep hygiene recommendations is especially relevant for this population, findings may not generalize to young adults who do not drink alcohol. That being said, > 40% of U.S. adults between ages 18 and 34 years report binge drinking in the past month; thus, the data are relevant for a large portion of young adults in the general population.[7] Participants in this sample also reported drinking amounts similar to those of participants in studies aiming to reduce alcohol use among young adults.[57] Third, women were overrepresented in our sample (75%). Although rates of insomnia are higher among women than among men,[58] research is needed to determine whether sex may moderate any of the proposed associations.

Conclusions drawn from these data are also limited by certain aspects of our methodology. For example, sleep hygiene behaviors could be conceptualized as either a cause or consequence of poor sleep health: Poor sleep hygiene may lead to poor sleep quality, but poor sleep quality may also lead one to engage in poor sleep hygiene (eg, long naps, excessive use of caffeine). In this study, we consider the impact of sleep hygiene behaviors on subsequent nighttime sleep; however, future studies may consider the potentially bidirectional association between these constructs. Moreover, although multilevel models are ideal for parsing within- from between-person effects, they do not establish causality. Therefore, none of the associations described as significant in this manuscript should be interpreted as causal. Finally, in an effort to be consistent and concrete in recommendations, we provided explicit time frames for various sleep hygiene recommendations (eg, "avoid bright lights in the 30 minutes before bedtime"). It is unclear whether these time frames had an impact on participants' reported use of various recommendations. Replication of these findings is highly encouraged.

CONCLUSIONS

Studies examining between-person associations between modifiable sleep behaviors and subsequent nighttime sleep have reported mixed results.[17,20,21,36] This study is the first to examine within-person associations between sleep hygiene practices and nighttime sleep at the daily level. Results of this study suggest that only a few sleep hygiene practices are associated with subsequent nighttime sleep at the daily level; specifically, prioritizing a comfortable sleep environment, limiting naps, and maintaining a consistent wake time. In contrast to traditional sleep hygiene recommendations, participants in this sample also recorded better self-reported (but not objective) sleep on nights that they drank within 2 hours of bedtime; however, this finding may be unique to heavy drinkers with insomnia because the opposite association has been found among lighter/non-drinkers who were not selected on the basis of insomnia.[44,46,47] Although this study provides support for a limited number of sleep hygiene recommendations, additional studies are needed to understand the daily impact of modifiable sleep behaviors in the general population and across the lifespan.

ABBREVIATION

CBT-I, cognitive behavioral therapy for insomnia

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