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Cannabis and Alcohol Use for Sleep Aid: A Daily Diary Investigation

Patricia A. Goodhines, **Les A. Gellis**, **Emily B. Ansell**, **Aesoon Park**

Department of Psychology, Syracuse University.

Abstract

Objective: One in five college students use substances such as cannabis and/or alcohol to help sleep. Despite this high prevalence of sleep aid use, there remains a lack of research on the potential day-to-day sleep- and substance-related consequences. The current study examined associations of cannabis and alcohol sleep aid use with subsequent sleep and substance use consequences among college students.

Methods: Of a baseline sample of 217 college students endorsing past-month cannabis and/or alcohol use (1% cannabis only, 42% alcohol only, 58% both), 83 students endorsing past-month cannabis and/or alcohol use *for sleep aid* (mean age=19.33 [*SD*=1.11], 30% male, 72% White) completed online questionnaires for 14 consecutive days to report daily sleep, substance use, and negative substance consequences.

Results: Multilevel models demonstrated that nights of cannabis sleep aid use predicted longer same-night sleep duration, shorter same-night wake-time after sleep onset, and greater next-day daytime fatigue within-person, after controlling for daily cannabis frequency. Alcohol sleep aid use was not associated with sleep-related outcomes or negative drinking consequences after controlling for daily alcohol quantity; these null results may be due to a low frequency of alcohol sleep aid use (1% of observations) over 14 days of assessment.

Conclusions: Results highlight daytime fatigue as a potential adverse short-term outcome of cannabis sleep aid use, despite its proximal sleep-related benefits.

Keywords

self medication; alcohol; cannabis; sleep; multilevel analysis

A recent study showed that 14–15% of college students use cannabis and 7–10% use alcohol to help sleep (Goodhines et al., 2017). However, experimental studies offer mixed support for the notion that sleep aid users sleep better than non-users on average (see Garcia & Salloum, 2015). Acute effects of pre-sleep cannabis administration include greater subjective sleep satisfaction (Bedi et al., 2010), longer sleep duration, shorter sleep onset latency (i.e., duration from bedtime to sleep initiation), and improved sleep maintenance (Cousens & DiMascio, 1973; Tassinari et al., 1999) the same night, but also increased next-

Correspondence concerning this article should be addressed to Aesoon Park, Department of Psychology, Syracuse University, Syracuse, NY 13244. aepark@syr.edu.

day fatigue (Nicholson et al., 2004). Acute effects of pre-sleep alcohol administration include improved subjective sleep quality, shorter sleep onset latency, and longer sleep duration (Roehrs et al., 1991; 1996; 2018) the same night, but also greater sleep disruption during the night (Arnedt et al., 2011) and next-day fatigue (Chait & Perry, 1994).

Despite extensive experimental evidence, ecologically-valid research on sleep-related consequences of cannabis and alcohol consumed with *intention* to aid sleep remains limited. Theoretical models of reciprocal influences between sleep and substance use outline a feed-forward cycle exacerbating consequences in both domains over time (Brower, 2003; Edwards, Reeves, & Fishbein, 2015), and substance use for sleep aid has been highlighted as a salient risk factor in this feed-forward process (Babson, Sottile, & Morabito, 2017). That is, sleep problems prompt individuals to self-medicate for sleep initiation, which further impairs sleep due to toxicity on sleep-related brain systems, which in turn requires higher doses of sleep aid, and so on, thus increasing sleep- and substance-related risk over time. Further, consecutive days of cannabis or alcohol use for sleep aid may promote development of tolerance (Bedi et al., 2010; Roehrs et al., 2018), subsequently prompting escalation of self-administered pre-sleep cannabis or alcohol use. As sleep problems persist and substance use presumably increases, susceptibility to substance-related consequences likely increases as well. For example, both cannabis and alcohol use during college have demonstrated associations with impaired academic, cognitive, and interpersonal functioning, as well as substantial risk-taking behaviors (e.g., driving under the influence; Pearson, Liese, & Dvorak, 2017; White & Hingson, 2013). When consumed specifically with intention to aid sleep, cannabis/alcohol sleep aid use has been associated with exacerbated negative consequences of existing alcohol use over time (Goodhines et al., 2017). Thus, despite a lack of empirical consideration, sleep aid use may precipitate substance-related consequences among college students.

Substance use during the developmental college years may have implications for future health trajectories. Substance use in college is influenced by developmental changes in emerging adulthood (e.g., decreased parental monitoring), as well as environmental (e.g., residential campus living) and psychosocial (e.g., saliency of peer norms) factors unique to college (Skidmore, Kaufman, & Crowell, 2016). Though many students “mature out” of risky substance use after college (Arria et al., 2016a; Kosty et al., 2017), substance use during college has been shown to impact future health problems and impairment. For example, frequent college cannabis users demonstrated more physical health visits and illness days (compared to non-using peers) up to 10 years later (Arria et al., 2016b). Further, risky drinking among college-age youth has demonstrated associations with future substance dependence and associated adverse consequences (for a review, see Krieger et al., 2018). Given the substantial developmental health impacts of college substance use, it is critical to better understand the prevalence and consequences of specific substance use patterns during college, such as cannabis and alcohol use for sleep aid.

Several important gaps remain in the literature. First, studies investigating consequences of cannabis and alcohol sleep aid use in college students are limited, despite evidence that college years represent a distinct developmental stage (Arnett, 2016; National Center for Education Statistics, 2016) characterized by inconsistent sleep-wake schedules and sleep-

impeding behaviors (Gellis et al., 2014) and prevalent cannabis and alcohol use (Johnston et al., 2015). Second, while previous between-person findings characterize outcomes of sleep aid use on average, little is known about within-person effects; that is, how individuals' day-to-day experiences and behaviors vary as a function of sleep aid use. Intensive repeated assessment methods are therefore needed to examine nuanced associations between sleep aid use and associated outcomes within students in daily college life.

The current daily diary study examined within-person associations of daily cannabis and alcohol sleep aid use with proximal, subjectively-measured sleep-related outcomes (i.e., same-night poor sleep quality rating, sleep duration, sleep onset latency, and wake-time after sleep onset, and next-day daytime fatigue) and next-day negative cannabis and alcohol consequences among college students across a 14-day period. It was hypothesized that: (a) nights of cannabis and alcohol sleep aid use would each predict better same-night sleep quality rating and shorter sleep onset latency, but also greater next-day daytime fatigue, within-person; (b) nights of cannabis sleep aid use would predict longer sleep duration and shorter wake-time after sleep onset, whereas nights of alcohol sleep aid use would predict shorter sleep duration and longer wake-time after sleep onset, within-person; (c) nights of cannabis sleep aid use would predict more next-day negative cannabis consequences and nights of alcohol sleep aid use would predict more next-day negative alcohol consequences, within-person.

Method

Participants and Procedure

Baseline and daily data was obtained from 217 college students endorsing past-month cannabis and/or alcohol use (1% cannabis only, 42% alcohol only, 58% both; mean age=19.38 [*SD*=1.17], 24% male, 73% White) recruited from psychology courses at a four-year university in New York state; recreational cannabis use remains illegal in New York State and medical cannabis prescriptions may be obtained by individuals over the age of 18 diagnosed with a severely debilitating or life-threatening condition (e.g., cancer; The New York State Senate, 2017). Students were eligible to participate if they (a) were an undergraduate student, (b) were aged 18–25 years, (c) were English-speaking, and (d) had used cannabis and/or alcohol at least once during the past 30 days. Daily multilevel analysis (see Data Analytic Strategy) was conducted with a subset of the full sample who endorsed past-month cannabis and/or alcohol use for sleep aid at baseline (n=83 students; mean age=19.33 [*SD*=1.11], 30% male, 72% White); during the 14-day assessment period, 1,045 observations were obtained from this subsample of sleep aid users (90% completion rate). Students were compensated with course credit scaled according to number of surveys completed.

Study procedures were approved by the Institutional Review Board at Syracuse University. At an initial lab appointment, eligible participants provided written informed consent, completed a baseline web-based survey, and obtained instructions for completing web-based "daily waking surveys" for the following 14 days. Beginning the following Monday, via preferred method of email or text message, participants received a link for the daily waking survey at 6:00 a.m. each morning and a reminder at 11:00 a.m. if needed. Daily waking

surveys prompted reporting about previous-day functioning (e.g., affect, fatigue) and previous-night sleep, required approximately five minutes to complete, and were due by 3:00 p.m. each day. The 14-day time frame is consistent with recommendations for daily sleep assessment (Buysse et al., 2006; Gunthert & Wenze, 2012) and is sufficient to observe cannabis and alcohol sleep aid use given the demonstrated frequency of use 1–2 nights per week in a previous study of college students (Goodhines et al., 2017).

Measures

Baseline sleep aid use.—Two items (Goodhines et al., 2017) assessed past-month frequency of cannabis and alcohol use "to help sleep" rated on an 8-point Likert scale ranging from 0 (*I did not use this substance to help fall asleep in the past month*) to 7 (*every day*). Item and response wordings were adapted from the original 2-week time frame to accommodate the current past-month assessment. Dichotomized scores (0=*no*, 1=*yes*) were used for analyses.

Baseline sleep and associated functioning.—The 19-item Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) measured global sleep quality. Individual items measured specific quantitative (e.g., duration) and subjective (i.e., quality rating) aspects of sleep. Scores of five or greater (possible range=0–21) indicate significant sleep disturbance. The 9-item Fatigue Severity Scale (Krupp et al., 1989) assessed daytime fatigue (e.g., "Fatigue causes frequent problems for me."). Response options were based on a 6-point Likert scale ranging from 0 (*strongly disagree*) to 6 (*strongly agree*) and a sum score was used (Cronbach's α=.90). Insomnia status at baseline was assessed using items reflecting DSM-5 criteria (American Psychiatric Association, 2013).

Baseline substance use and problems.—One item assessed past-month cannabis frequency (Dennis, 1999), with responses on an adapted 8-point Likert scale (0=*I did not use any cannabis in the past month*, 1=*Once during the past month*, 2=*2–3 times*, 3=*Once a week*, 4=*Twice a week*, 5=*3–4 times a week*, 6=*5–6 times a week*, 7=*Every day)*. The 50-item Marijuana Consequences Questionnaire (Simons et al., 2012) assessed past-month negative cannabis consequences, adapted from the original 6-month timeframe. Responses were coded dichotomously (0=*no*, 1=*yes*) and a count score was used. Two items (NIAAA; 2003) measured past-month alcohol frequency, with responses on an 8-point Likert scale (same as used for the cannabis frequency item), and typical quantity, with responses on a 10-point Likert scale (0=*1 drink*, 1=*2 drinks*, 2=*3–4 drinks*, 3=*5–6 drinks*, 4=*7–8 drinks*, 5=*9–11 drinks*, 6=*12–15 drinks*, 7=*16–18 drinks*, 8=*19–24 drinks*, 9=*25 or more drinks*). The 48-item Young Adult Alcohol Consequences Questionnaire (Read et al., 2007) assessed past-month negative alcohol consequences, adapted from the original 6-month timeframe. Responses were coded dichotomously (0=*no*, 1=*yes*) and a count score was used. Four items used an 8-point Likert scale (same as the cannabis frequency item) to assess past-month frequency of tobacco use ("During the past month, how often did you usually use any kind of tobacco?") and over-the-counter, prescription, and narcotic sleep aid use ("During the past month, how often did you use over-the-counter medication/prescribed sleep medication/a narcotic other than heroin [for example, methadone, opium, morphine, codeine, Demerol, Vicodin, OxyContin, and Percocet] to help you sleep?"). One item ("On how many

occasions [if any] have you taken stimulant medications such as Ritalin or Adderall on your own [that is, without a doctor telling you to take them] in the last 30 days?") used a 7-point Likert scale (0=*0 occasions*, 1=*1–2*, 2=*3–5*, 3=*6–9*, 4=*10–19*, 5=*20–30*, 6=*40 or more*) to assess past-month frequency of stimulant misuse (Johnston, Bachman, & O'Malley, 2007).

Baseline demographics and mood.—Sex, age, class year, race, country of origin, full-time student status (0=*full-time*, 1=*part-time*), working status (0=*full-time*, 1=*part-time*, 2=*not working*), residence type (0=*off campus*, 1=*on campus*), and fraternity/sorority affiliation (0=*non-member*, 1=*member*) were assessed. The 4-item Patient Health Questionnaire assessed past-month frequency of depression and anxiety symptoms (Kroenke et al., 2009), adapted from the original 2-week timeframe. Response options were based on a 4-point Likert scale ranging from 0 (*not at all*) to 3 (*nearly every day*) and a sum score was used (Cronbach's α=.81).

Daily substance use for sleep aid and non-sleep aid.—One item assessed daily cannabis frequency ("How many times did you use marijuana yesterday?"). Daily cannabis quantity was not assessed in the current study due to its psychometric concerns (Cuttler & Spradlin, 2017; Prince, Conner, & Pearson, 2018). If cannabis use was reported, seven items from the Marijuana Motives Questionnaire were presented to assess reasons for using cannabis, including the highest-loading item from each of the five factors from the original measure among a college student sample (Simons et al., 1998): "To forget my worries," "Because I like the feeling," "Because it makes social gatherings more fun," "To be liked," and "To expand my awareness"; one additional motive ("To help sleep") isolated cannabis sleep aid use. Responses were coded dichotomously (0=*no*, 1=*yes*). One item assessed daily alcohol quantity ("How many drinks containing alcohol did you have yesterday?"). If alcohol use was reported, six items from the Drinking Motives Questionnaire (Cooper, 1994) were presented to assess reasons for drinking, including the highest-loading items from four factors of the original measure as determined by factor analysis (sample from Goodhines et al., 2017): "To forget your worries," "So that others won't kid you about not drinking," "Because it's exciting," "Because it makes social gatherings more fun"; one additional motive ("To help sleep") isolated alcohol sleep aid use. Responses were coded dichotomously (0=*no*, 1=*yes*). Five items assessed daily tobacco frequency ("How many times did you use tobacco and/or nicotine yesterday?"; motives and consequences of daily tobacco use were not assessed), caffeine quantity ("How many caffeinated drinks did you have yesterday?"), over-the-counter and prescription sleep aid use ("Did you take any over-the-counter medication to help you fall asleep last night?"; "Did you take any prescription medications that are prescribed to you to help you sleep last night?"), and stimulant misuse ("Did you take any stimulant medications [e.g., Ritalin, Adderall] not prescribed to you yesterday?").

Daily sleep and associated functioning.—Selected items from the Expanded Consensus Sleep Diary for Morning (Carney et al., 2012) were used, including poor sleep quality rating ("How would you rate the quality of your sleep?"; responses options: 0 [*very good*] to 5 [*very poor*]), sleep duration ("In total, how long did you sleep?"; responses scaled to hours), sleep onset latency ("How long did it take you to fall asleep?"; responses scaled to

minutes), wake-time after sleep onset ("How many times did you wake up, not counting your final awakening?" followed by "In total, how long did these awakenings last?"; responses scaled to minutes), and daytime fatigue ("How fatigued did you feel during the day yesterday?"; response options: 0 [*not fatigued*] to 4 [*very fatigued*]).

Daily negative cannabis and alcohol consequences.—Daily negative cannabis consequences were assessed using 14 items selected from the Brief Marijuana Consequences Questionnaire (Simons et al., 2012). Seven items not appropriate for daily assessment were excluded from the original 21 items (e.g., "I have been overweight because of my marijuana use") and wording was adapted to fit the context of previous-day drinking episodes (e.g., "I have driven a car when I was high" was changed to "I drove a car when I was high"). Responses were coded dichotomously (0=*no*, 1=*yes*) and a count score was used. Daily negative alcohol consequences were assessed using 22 items selected from the Brief Young Adult Alcohol Consequences Questionnaire (Kahler, Strong, & Read, 2005). Two items not appropriate for daily assessment were excluded from the original 24 items and wording was similarly adapted. Responses were coded dichotomously (0=*no*, 1=*yes*) and a count score was used.

Daily affect.—A 4-item adaptation of the Positive and Negative Affect Schedule (Bagozzi, 1993) assessed daily depressive and anxious affect on a 5-point Likert scale ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). A sum score (Cronbach's α=.85) was used.

Data Analytic Strategies

Descriptive statistics, independent-sample *t*-tests and chi-square analyses comparing sleep aid users (i.e., endorsed past-month cannabis and/or alcohol sleep aid use at baseline; *n*=83) to non-sleep aid users (*n*=134; Table 1), and bivariate correlations (Table S1) were computed in SPSS Version 24.0 (IBM Corp., 2016) using all available data.

Multilevel models using data from sleep aid users only (*n*=83) examined associations of cannabis sleep aid use (Table 2) and alcohol sleep aid use (see Table 3) with daily sleep- and substance-related outcomes, respectively. Models of continuous outcomes (same-night poor sleep quality rating, sleep duration, sleep onset latency, and wake-time after sleep onset, and next-day fatigue) were conducted with *SPSS*, Version 24.0 MIXED procedure using full information maximum likelihood estimation and first-order autoregressive covariance structure. Models of discrete outcomes (negative cannabis and alcohol consequences) were estimated with a negative binomial distribution in *Mplus*, Version 7.4 (Muthén & Muthén, 2012) using full information maximum likelihood estimation with robust standard errors. Unconditional models and Intraclass Correlation Coefficients (ICC) estimated percentage of variance due to between-person (versus within-person) differences.

Level 2 was defined by participants (*N*=83) and level 1 was defined by study days (*n*=14) nested within participants. Between-person differences (sample-mean centered) were separated from within-person fluctuations in daily predictors (person-mean centered) and included in the models to control for sample-level trends. Fixed effects at level 2 (i.e., between-person predictors) included average sleep aid use, as well as: (a) a mean-centered, linear time trend scaled to units of weeks (i.e., 14 study days represented as values ranging

from −1 to +1) to account for the passage of study days; (b) a dichotomized weekend variable (i.e., Friday and Saturday versus weekdays; determined by exploratory day-of-week analyses in the current sample) to account for day-of-the-week effects typically observed in sleep timing/duration (Gaultney, 2010) and substance use and consequences (Bravo et al., 2017); (c) daily negative affect; (d) cannabis and tobacco frequency (in cannabis sleep aid models) or alcohol quantity (in alcohol sleep aid models). Notably, this study was not designed (and is underpowered) to test between-person effects, which were therefore not interpreted. Fixed effects at level 1 (within-person predictors) included time-lagged (previous-day) and concurrent (same-day) sleep aid use, negative affect, and cannabis/tobacco or alcohol use. Inclusion of both time-lagged and concurrent predictors established a temporal process within the model, thereby conservatively controlling for the extent to which a prior day's behavior (i.e., sleep aid use in the current study) influenced individual responsiveness to the same behavior the following day (Bolger, Davis, & Rafaeli, 2003; Wickham & Knee, 2013). Thus, although effects of same-night sleep aid use on sleep and previous-night sleep aid use on daytime functioning were of primary interest, models additionally controlled for the temporally-lagged effects of: (a) the previous-night (in addition to the same night) sleep aid use on the current night's sleep quality rating, duration, onset latency, and wake-time after sleep onset; (b) two-previous-night (in addition to the previous-night) sleep aid use on the current day's fatigue and negative alcohol/cannabis consequences. Inclusion of time-lagged predictors is consistent with previous daily studies modelling within-person consequences of cannabis use (e.g., Ansell et al., 2015; Trull et al., 2016) and sleep (e.g., Lee et al., 2017). Notably, significance patterns of main analyses remained consistent regardless of inclusion of time-lagged covariate effects. Random effects at level 1 captured residual measurement error (not calculated for discrete outcomes; see Bolger & Laurenceau, 2013).

Proportion reduction in variance was calculated to measure local effect size of daily cannabis/alcohol sleep aid use (Raudenbush & Bryk, 2002). Difference in within-person (level 1) intercept variance from models with and without sleep aid use predictors (but all the same covariates) was calculated and divided by the within-person intercept variance of the latter. For models finding significant within-person effects of sleep aid use on respective outcomes, models were tested in the reverse direction (e.g., the effect of within-person daily sleep quality rating on next-day sleep aid use) with the same covariates to confirm directionality of the association; models were estimated with a negative binomial distribution using full information maximum likelihood estimation with robust standard errors to accommodate the discrete outcome.

Ancillary analyses.—Four sets of ancillary multilevel analyses were conducted to: (a) investigate associations restricted to substance-specific sleep aid users (n=68 cannabis sleep aid users and n=32 alcohol sleep aid users) rather than the combined sample of all sleep aid users (n=83) ; (b) account for accuracy of retrospective recall by additionally controlling for the within-person effect of time elapsed between final awakening and survey completion (i.e., times of day that individuals completed their daily waking surveys); (c) assess whether general cannabis/alcohol use (regardless of motive) resulted in a consistent pattern of significant sleep- and substance-related outcomes; (d) assess the possible cross-level

moderating effect of insomnia status on associations of sleep aid use with sleep- and substance-related outcomes, which have been observed in the pre-sleep alcohol administration literature (Roehrs et al., 1999).

Power analyses.—Power analyses were conducted (PINT; Bosker, Snijders, & Guldemond, 1996) to estimate power for a multilevel model to detect within-person effects of cannabis/alcohol sleep aid on time-varying outcomes (e.g., sleep quality rating) after accounting for covariates. Assuming small within-group and between-group covariance (0.10) and a residual variance of 0.50, daily data obtained from 83 sleep aid users for 14 days had sufficient power (> .80) to detect within-person effects of sleep aid use.

Results

Descriptive Analyses

Descriptive statistics and comparisons of sleep aid users (n=83) to non-sleep aid users (n=134) across all variables are presented in Table 1. At baseline, 38% of students endorsed past-month cannabis and/or alcohol for sleep aid use, 85% reported poor global sleep quality (M=6.58; SD=2.34), and on average students reported sleeping approximately 7 hours per night, using cannabis 2–3 times during the past month, and drinking once per week at 5–6 drinks per occasion. In general, participants did not report frequent use of substances aside from alcohol and cannabis. At baseline, sleep aid users reported higher negative mood, frequency of cannabis, alcohol, and other substance use (e.g., tobacco), negative cannabis and alcohol consequences, and poorer global sleep quality compared to non-users.

Across the 14-day diary period, sleep aid users reported higher negative affect, cannabis frequency and alcohol quantity, negative cannabis and alcohol consequences, and poorer subjective sleep quality compared to non-users. During the 14-day diary period, past-month sleep aid users used cannabis 4 days (SD=4.48; median=7 days) on average and 35% reported cannabis sleep aid use at least once (n=29 students; 10% of daily observations; observed range: 0–13 nights out of 14; median=6 nights); past-month sleep aid users used alcohol 3 days (SD=2.55; median=5 days) on average and 7% reported alcohol sleep aid use at least once (n = 6 students; 1% of daily observations; observed range: 0–3 nights out of 14; median=1 night). Although 29% of students endorsed over-the-counter sleep aid use and 13% endorsed stimulant misuse during the past month at baseline, only 4% of daily observations represent nights of over-the-counter sleep aid use and 1% represent days of stimulant misuse, indicating that these behaviors occurred infrequently in this sample. Bivariate correlations among the full sample (N=217) are presented in Table S1.

Multilevel Analyses of Daily Sleep Aid Use

Unconditional models demonstrated within-person variability in poor sleep quality rating (ICC=.14), sleep duration (ICC=.14), sleep onset latency (ICC=.14), wake-time after sleep onset (ICC=.19), daytime fatigue (ICC=.26), and negative cannabis consequences (ICC=.41) and negative alcohol (ICC=.04) across the 14-day study period.

Cannabis sleep aid.—As shown in Table 2, cannabis sleep aid predictors accounted for a proportion reduction in within-person intercept variance for daily poor sleep quality rating (0.11%), sleep duration (0.33%), wake-time after sleep onset (7.06%), daytime fatigue (0.50%), and negative cannabis consequences (1.17%). Cannabis sleep aid predictors accounted for a proportion increase in within-person intercept variance for sleep onset latency (0.12%).

Sleep-related outcomes.: Inconsistent with *a priori* hypotheses, within-person findings indicated that daily cannabis sleep aid use was not associated with poor sleep quality either the same (γ=−0.07, p=.61) or the following (γ=0.07, p=.62) night.

Consistent with hypotheses, within-person findings indicated that daily cannabis sleep aid use was associated with greater sleep duration the same night (γ=0.64, p=.04), but not the following (γ=−0.11, p=.72). When tested in reverse, within-person findings indicated that neither previous-night nor time-lagged (two nights previous) sleep duration was associated with subsequent cannabis sleep aid use (IRR=1.05, 95% CI [0.97, 1.12], p=.28; IRR=1.02, 95% CI [0.92, 1.12], p=.72); thus, cannabis sleep aid use was associated with subsequent sleep duration, but not vice versa.

Inconsistent with hypotheses, within-person findings indicated that daily cannabis sleep aid use was not associated with sleep onset latency either the same (γ=−1.25, p=.77) or the following (γ=−1.31, p=.76) night.

Consistent with hypotheses, within-person findings indicated that daily cannabis sleep aid use was associated with decreased wake-time after sleep onset the same night (γ=−13.74, p=.003), but not the following (γ=4.18, p=.37). When tested in reverse, within-person findings indicated that neither previous-day nor time-lagged (two nights previous) wake-time after sleep onset was associated with subsequent cannabis sleep aid use (IRR=1.00, 95% CI [0.98, 1.01], p=.71; IRR=0.99, 95% CI [0.97, 1.00], p=.23); thus, cannabis sleep aid use was associated with subsequent wake-time after sleep onset, but not vice versa.

Consistent with hypotheses, within-person findings indicated that daily cannabis sleep aid use was associated with higher daytime fatigue the following day (γ=0.34, p=.046), but not the day after that (γ=0.00, p=.99). When tested in reverse, within-person findings indicated that neither concurrent (same-day) nor time-lagged (previous-day) daytime fatigue was associated with subsequent cannabis sleep aid use (IRR=0.95, 95% CI [0.78, 1.12], p=.64; IRR=1.01, 95% CI [0.86, 1.15], p=.96); thus, cannabis sleep aid use was associated with subsequent daytime fatigue, but not vice versa.

Substance-related outcomes.: Inconsistent with hypotheses, within-person findings indicated that daily cannabis sleep aid use was not associated with negative cannabis consequences either the following day (IRR=1.37, 95% CI [0.75, 1.99], p=.25) or the day after that (IRR=0.84, 95% CI [0.50, 1.81], p=.48).

Alcohol sleep aid.—As shown in Table 3, alcohol sleep aid predictors accounted for a proportion reduction in within-person intercept variance for daily poor sleep quality rating

(0.41%), sleep duration (0.001%), sleep onset latency (0.15%), wake-time after sleep onset (0.05%), daytime fatigue (0.41%), and negative alcohol consequences outcomes (0.03%). Inconsistent with hypotheses, within-person findings indicated that alcohol sleep aid use was not associated with any daily outcomes (p's>.05).

Ancillary Multilevel Analyses

The first set of multilevel models using subsamples (n=32 alcohol and n=68 cannabis sleep aid users, rather than n=83 combined sleep aid users) yielded largely consistent significance patterns; however, the within-person effect of daily cannabis sleep aid use on same-night sleep duration was non-significant for cannabis sleep aid users (γ=0.35, p=.27). The second set of models additionally controlling for the within-person effect of time elapsed between final awakening and survey completion (M=1.56, SD=1.99) yielded significance patterns consistent with main analyses. The third set of models assessing effects of general cannabis and alcohol use (regardless of motive) yielded unique significance patterns: days of greater cannabis frequency were associated with shorter sleep onset latency (γ=−2.62, p=.02) and greater next-day negative cannabis consequences (IRR=1.21, γ=0.19, p=.047), but were not associated with any other sleep-related outcomes within-person (p's>.05); days of greater alcohol quantity were associated with poorer same-night sleep quality rating (γ=0.04, p<.001), shorter same-night sleep duration (γ=−0.06, p=.02), reduced same-night sleep onset latency (γ=−0.95, p=.02), and fewer negative alcohol consequences both the next day (IRR=0.89, γ=−0.12, p=.004) and the following day (IRR=0.87, γ=−0.14, p=.001) within-person. Further, the fourth set of ancillary analyses demonstrate that insomnia significantly moderated associations of cannabis sleep aid use with same-night sleep duration within-person (γ=2.06, p=.01); specifically, individuals *without* insomnia experienced a longer sleep duration following cannabis sleep aid use (versus non-use). Non-significant cross-level moderation effects were found for all other sleep- and substance-related outcomes (p's>.05).

Discussion

This study examined associations of cannabis and alcohol sleep aid use with subsequent sleep- and substance-related consequences among college students in daily life. Sleep aid users demonstrated greater negative affect, sleep problems, and substance use and consequences relative to non-sleep aid users, which is largely consistent with previous findings from a sample of college drinkers (Goodhines et al., 2017). Multilevel modeling analyses indicated that cannabis sleep aid use may improve same-night sleep maintenance and duration within individuals; however, it does not improve subjective sleep quality or sleep onset latency, and actually increases fatigue the following day. Alcohol sleep aid use was not associated with any change in outcomes, possibly due to a low frequency of alcohol sleep aid use (1% of observations) over 14 days. Within-person findings are an incremental contribution to limited research in this area, as disaggregation of within-person fluctuations around individual averages eliminated the potential confound of sample-level trends and allowed for directional modeling of day-to-day relationships. By repeatedly sampling participant responses in daily life within the natural environment, findings are directly generalizable to the daily lives of college students.

Cannabis sleep aid users sampled in the current study were likely regular cannabis users, as evidenced by associations of cannabis sleep aid use with general cannabis and cannabis sleep aid use frequency (median=6 nights out of 14). Thus, these students may use cannabis for sleep simply because they consume cannabis for a wider array of reasons relative to low-moderate using peers (Bonn-Miller & Zvolensky, 2009). However, cannabis use consumed with the *intention to improve sleep* has not been included in widely-used cannabis motives assessments, although substance use behavior motivated by different needs is theorized to be characterized by unique patterns of consequences (see Cooper, 1994). The current study remedied this gap by investigating outcomes of cannabis sleep aid, after controlling for daily cannabis frequency.

Cannabis sleep aid may be associated with improvement in sleep. Consistent with experimental evidence for between-person associations (e.g., Tassinari et al., 1999), within-person findings demonstrated that nights of cannabis sleep aid use predicted longer sleep duration and better sleep maintenance within-person. Within-person effects observed after controlling for sample-level trends suggest that previous between-person findings might be better explained by within-person variability; that is, proximal state changes in sleep maintenance and duration associated with cannabis sleep aid use may represent as more stable, characteristic differences when sleep aid use occurs more regularly. Notably, nights of cannabis sleep aid use did not predict same-night sleep duration among a subsample of past-month cannabis sleep aid users (n=68). Ancillary analyses also revealed a significant effect of cannabis sleep aid use on longer same-night sleep duration only for individuals *without* insomnia; however, replication is needed given that the small percentage of individuals with insomnia among sleep aid users (13%) may be underpowered to accurately detect cross-level moderation effects. Continued research with larger samples and longer assessment periods is needed to further investigate replicability of these findings among regular cannabis sleep aid users and individuals with insomnia.

Contrary to popular belief among college students (Digdon, 2010), cannabis sleep aid use may *not* be associated with improvement in subsequent sleep initiation or subjective quality. Inconsistent with experimental evidence for between-person associations (e.g., Bedi et al., 2010), nights of cannabis sleep aid use did not predict significant change in same-night sleep onset latency or sleep quality ratings within-person. One explanation for these discrepant findings is that cannabis sleep aid use actually prevents sleep onset latency and sleep quality from deviating substantially from individual averages, thereby minimizing within-person variability. Alternatively, dosage, potency, administration method, and timing of pre-sleep cannabis use in experimental studies likely do not accurately reflect self-initiated cannabis sleep aid use by modern college students (Bowles, Herzig, & Shea, 2017; Chandra et al., 2019). Therefore, it is recommended that future studies assess cannabis-related moderators of the associations between cannabis sleep aid use and sleep-related outcomes among college students.

Despite proximal sleep-related benefits, findings highlight daytime fatigue as a potential short-term consequence of cannabis sleep aid use. Consistent with experimental evidence for between-person associations (Chait, Fischman, & Schuster, 1985), nights of cannabis sleep aid use predicted increased next-day daytime fatigue within-person. Again, within-person

effects observed after controlling for sample-level trends suggest that previous between-person findings might be better explained by within-person variability. Increases in subsequent daytime fatigue might be explained by cannabis' predictable impact on sleep architecture, such that slow wave sleep is enhanced (Freemon, 1982) and REM sleep and density is decreased (Tassinari et al., 1999). Thus, while sleep duration and maintenance is improved, sleep obtained is actually less restorative, resulting in increased next-day fatigue.

Due to infrequent endorsement during the assessment period, findings regarding alcohol sleep aid use remain preliminary and may be used to guide future research. Although 32 students reported past-month alcohol sleep aid at baseline, only six of these students reported any alcohol sleep aid use during the 14-day diary period (i.e., 8 observations out of 1045; 1%). This discrepancy is likely due to infrequent alcohol sleep aid use occurring among the current sample (median=1 night out of 14). Null findings may be explained by insufficient power for detection of within-person effects, or by the current novel and conservative statistical approach of investigating the effects of alcohol sleep aid use on outcomes *over and above daily alcohol quantity*. Continued research sampling regular alcohol sleep aid users over longer assessment periods is needed to further investigate associations of alcohol sleep aid use with subsequent sleep- and substance-related consequences among college students.

Ancillary analyses highlight important differences in the within-person effects of general substance use versus substance use specifically for sleep aid. In contrast to main analyses of cannabis sleep aid use, days of greater cannabis frequency were associated with reduced same-night sleep onset latency, but also more next-day negative cannabis consequences. This discrepancy may be attributable to unique effects of cannabis consumed with *intention* to aid sleep, supporting the consideration of sleep-related motives as a unique predictor of sleep outcomes. Similar model comparisons with alcohol sleep aid use are not possible because, although recommended, the 14-day timeframe was likely too brief to capture the phenomena of alcohol sleep aid use in college students. In contrast to underpowered main analyses of alcohol sleep aid use, sufficiently-powered ancillary analyses revealed that days of greater alcohol quantity were associated with reduced same-night sleep onset latency and fewer next-day negative alcohol consequences, but also poorer sleep within-person. The current within-person alcohol-sleep findings contribute incrementally to a sparse body of research (e.g., Fucito et al., 2018).

Long-term consequences of college sleep aid users remain unknown. Many students "mature out" of substance use after college (Arria et al., 2016a; Kosty et al., 2017), partly due to the time-limited nature of contextually-nested reinforcers (e.g., peer approval; Skidmore et al., 2016). In contrast, sleep aid use is a "safety behavior" that aims to obtain and is reinforced by unique positive consequences (i.e., improved subjective quality; Harvey, 2005), which may differentially promote continued or even accelerated use after college. Tolerance to the sedative effects of cannabis and alcohol may develop in approximately one week of daily use (Bedi et al., 2010; Roehrs et al., 2018), after which point increasing dosages might be consumed to maintain subjective sleep-related gains (suggesting the potential for greater substance-related consequences) and/or withdrawal and rebound insomnia may occur upon cessation (see Garcia et al., 2015). Longitudinal cohort studies are necessary to investigate

cannabis and alcohol sleep aid use during college as a unique risk factor for continued or escalating use during adulthood.

Regarding limitations, data were drawn from a predominantly white and female sample at a private, northeastern university, warranting replication with more heterogeneous samples. Eligibility criteria required that participants endorse cannabis and/or alcohol use at least once in the past 30 days; thus current findings require replication among daily and/or heavy-using or clinical samples of substance users. Subjective assessments may have been vulnerable to self-reporting errors such as social desirability bias or memory impairment due to intoxication. Further, this study was under-powered for detection of between-person associations, requiring investigation with larger samples and/or longer assessment periods. Also, it is impossible to know what might have happened in the case of non-sleep aid use (i.e., the counterfactual; Collins, Hall, & Paul, 2004) given the observational design; however, this limitation is mitigated by the fact that each participant served as their own personal reference. Lastly, it is unclear whether the illegal nature of cannabis use in this New York state sample influenced results. Limited emerging evidence suggests that state-level recreational legalization may not significantly impact college students' cannabis use frequency (Jones, Jones, & Peil, 2018); however, potential changes in associated psychosocial consequences remain to be examined. Further, more than half of adults with cannabis prescriptions endorse use for off-label purposes (e.g., to treat other symptoms without physician recommendations; Morean & Lederman, 2019). Because prescribed cannabis may be used for sleep aid, the current findings suggest that psychoeducation about the physiological effects of cannabis use on subsequent sleep may be beneficial when prescribing medical cannabis to college students.

Several recommendations are offered for future assessment of sleep aid use behaviors. First, objective measurement of sleep was not obtained for this study; future research should utilize concurrent objective ambulatory assessment methods (e.g., actigraphy) to reduce retrospective self-report bias, particularly given possible cannabis-related memory errors (Broyd et al., 2016). Second, baseline and daily cannabis and alcohol use for sleep aid were assessed via single-item, dichotomous responses in attempt to minimize participant burden and maximize response rates; however, in the absence of a validated multi-item scale for assessment of sleep aid use, this single-item measure may have limited construct validity. A more comprehensive, psychometrically-validated assessment of sleep aid use behavior needs to be developed. Third, the current study did not assess event-level timing of cannabis and alcohol sleep aid use (versus general use). Given that effects of experimental alcohol administration on subsequent sleep have been shown to differ by timing of consumption (Van Reen et al., 2011; 2013), future studies should investigate timing of sleep aid use events as a moderator of associations between sleep aid use and sleep-related outcomes. Fourth, daily cannabis quantity was not assessed in this study, precluding investigation of dosage-specific effects of cannabis sleep aid use; future studies should assess event-level quantity of cannabis use (e.g., grams; Prince et al., 2018) in addition to daily frequency to better capture the short-term development of tolerance. Finally, additional research should investigate concurrent substance use for the manipulation of both sleep and wake states (e.g., cannabis to sleep and tobacco to wake up), possible interactive effects of polysubstance use, potential

moderating effects of other substance use motives (e.g., coping), and mechanisms underlying in-the-moment decisions to self-medicate for sleep aid.

Findings of this daily diary study highlight daytime fatigue as a potential adverse short-term outcome of cannabis sleep aid use, despite its proximal sleep-related benefits. Given the ecologically-valid design and novel within-person analysis providing directional modeling of day-to-day responses, this daily diary study represents an important incremental contribution to a limited area of research.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Means or Percentages of Study Variables as a Function of Past-Month Sleep Aid Use Reported at Baseline

	All Participants (*N*=217)	Sleep Aid Users (*n*=83)	Non-Sleep Aid Users (*n*=134)	Group Comparison between Sleep Aid Users vs. Non-Users
Baseline Variables (possible range)				
Demographics				
Male Sex	24%	30%	21%	$\chi^2(1)= 33.08^{***}$
Age	19.38 (1.17)	19.33 (1.11)	19.40 (1.21)	$t(202)=-1.62$
Freshman	30%	34%	28%	$\chi^2(1)= 11.90^{***}$
White Race	73%	72%	73%	$\chi^2(1)= 0.34$
Asian Race	11%	7%	14%	$\chi^2(1)= 27.68^{***}$
Black Race	8%	11%	6%	$\chi^2(1)= 24.00^{***}$
Multiracial	5%	7%	4%	$\chi^2(1)= 18.52^{***}$
Other Race	3%	2%	4%	$\chi^2(1)= 3.93^{*}$
U.S. Country of Origin	88%	89%	87%	$\chi^2(1)= 2.54$
Full-Time Student	100%	100%	99%	$\chi^2(1)= 8.78^{**}$
Not Working	72%	74%	71%	$\chi^2(1)= 2.40$
Living On Campus	74%	74%	74%	$\chi^2(1)= 0.06$
Greek Affiliation	32%	33%	32%	$\chi^2(1)= 0.06$
Negative Mood (0–12)	3.12 (2.85)	3.72 (2.88)	2.75 (2.76)	$t(215)= 9.23^{***}$
Sleep				
Global Sleep Quality (PSQI; 0–21)	6.58 (2.34)	7.23 (2.45)	6.18 (2.18)	$t(215)= 11.96^{***}$
Poor Sleep Quality Rating (0–3)	1.31 (0.59)	1.42 (0.60)	1.24 (0.58)	$t(215)= 8.26^{***}$
Sleep Duration (Hours)	6.80 (1.21)	6.69 (1.14)	6.87 (1.25)	$t(215)=-4.04^{***}$
Sleep Onset Latency (Minutes)	28.45 (22.30)	31.66 (22.54)	26.46 (21.92)	$t(215)= 6.25^{***}$
Weekly Frequency Waking After Sleep Onset (0–3)	1.59 (1.05)	1.53 (1.05)	1.63 (1.06)	$t(215)=-2.46^{*}$
Daytime Fatigue (0–54)	29.42 (10.57)	29.54 (9.94)	29.34 (10.94)	$t(215)= 0.52$
Cannabis				
Past-Month Cannabis Sleep Aid Frequency (0–7)	1.19 (2.11)	3.12 (2.37)	0.00 (0.00)	$t(215)= 44.93^{***}$
Past-Month Cannabis Frequency (0–7)	2.08 (2.43)	3.83 (2.51)	1.00 (1.61)	$t(215)= 34.31^{***}$
Negative Cannabis Consequences (0–50)	8.28 (7.71)	10.65 (8.04)	5.22 (6.01)	$t(215)= 16.23^{***}$
Alcohol				
Past-Month Alcohol Sleep Aid Frequency (0–7)	0.45 (1.22)	1.18 (1.74)	0.00 (0.00)	$t(215)= 23.17^{***}$
Past-Month Alcohol Frequency (0–7)	3.39 (1.33)	3.61 (1.36)	3.25 (1.30)	$t(215)= 7.47^{***}$
Past-Month Alcohol Quantity (0–9)	2.51 (1.21)	2.72 (1.16)	2.38 (1.23)	$t(215)= 7.84^{***}$
Negative Alcohol Consequences (0–48)	10.87 (8.45)	13.35 (9.36)	9.33 (7.43)	
Other Substance Use				

	All Participants (*N*=217)	Sleep Aid Users (*n*=83)	Non-Sleep Aid Users (*n*=134)	Group Comparison between Sleep Aid Users vs. Non-Users
Past-Month Tobacco Frequency (0–7)	1.32 (2.31)	2.45 (2.84)	0.62 (1.54)	$t(215)= 20.20^{***}$
Past-Month Over-the-Counter Sleep Aid Frequency (0–7)	0.73 (1.47)	0.78 (1.51)	0.69 (1.45)	$t(215)= 1.60$
Past-Month Prescription Sleep Aid Frequency (0–7)	0.17 (0.98)	0.23 (1.08)	0.13 (0.91)	$t(215)= 2.49^{*}$
Past-Month Narcotic Sleep Aid Frequency (0–7)	0.02 (0.27)	0.05 (0.44)	0.00 (0.00)	$t(215)= 3.76^{***}$
Past-Month Stimulant Misuse (0–6)	0.22 (0.63)	0.39 (0.83)	0.11 (0.42)	$t(215)= 12.36^{***}$
Daily Variables (possible range)				
Demographics				
Negative Affect (0–20)	6.50 (3.23)	7.24 (3.68)	6.08 (2.85)	$t(215)= 8.72^{***}$
Sleep				
Poor Sleep Quality Rating (0–5)	1.53 (0.91)	1.59 (0.92)	1.50 (0.91)	$t(215)= 2.58^{*}$
Sleep Duration (Hours)	7.55 (1.84)	7.47 (1.92)	7.59 (1.78)	$t(215)= -1.72$
Sleep Onset Latency (Minutes)	20.36 (46.00)	21.61 (41.27)	19.65 (48.52)	$t(215)= 1.10$
Wake-Time After Sleep Onset (Minutes)	13.95 (23.30)	14.62 (23.77)	13.57 (23.04)	$t(215)= 0.75$
Daytime Fatigue (0–4)	2.59 (1.12)	2.61 (1.12)	2.58 (1.11)	$t(215)= 0.54$
Cannabis				
Cannabis Sleep Aid (yes/no)	4%	10%	0%	$\chi^2(1)= 182.06^{***}$
Cannabis Frequency	0.32 (0.93)	0.68 (1.27)	0.11 (0.55)	$t(215)= 13.68^{***}$
Negative Cannabis Consequences (0–14)	0.13 (0.60)	0.31 (0.92)	0.03 (0.25)	$t(215)= 9.51^{***}$
Alcohol				
Alcohol Sleep Aid (yes/no)	0.38%	1%	0%	$\chi^2(1)= 6.25^{*}$
Alcohol Quantity	1.10 (2.55)	1.49 (3.01)	0.88 (2.22)	$t(215)= 5.74^{***}$
Negative Alcohol Consequences (0–22)	0.23 (0.94)	0.29 (0.99)	0.19 (0.92)	$t(215)= 2.65^{**}$
Other Substance Use				
Tobacco Frequency	0.19 (1.22)	0.45 (1.94)	0.04 (0.33)	$t(215)= 6.74^{***}$
Caffeine Quantity	0.57 (0.87)	0.64 (1.00)	0.53 (0.79)	$t(215)= 2.98^{**}$
Over-the-Counter Sleep Aid (yes/no)	4%	3%	5%	$\chi^2(1)= 6.24^{*}$
Prescription Sleep Aid (yes/no)	2%	2%	2%	$\chi^2(1)= 1.74$
Stimulant Misuse (yes/no)	1%	2%	1%	$\chi^2(1)= 6\ 1\ 5^{*}$

Note. *N*=217. “Other race” includes American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, and self-identification as “other.” The following baseline variables were obtained from individual items on the Pittsburgh Sleep Quality Index (PSQI): poor sleep quality rating, sleep duration, sleep onset latency, and weekly frequency of waking after sleep onset; higher scores indicate worse sleep quality, lower scores indicate better sleep quality.

$^{*}p<.05$.

$^{**}p<.01$.

$^{***}p<.001$.

Table 2

Multilevel Models of Daily Cannabis Sleep Aid Use Predicting Sleep-and Substance-Related Outcomes

	Same-Night Poor Sleep Quality Rating	Same-Night Sleep Duration	Same-Night Sleep Onset Latency	Same-Night Waketime After Sleep Onset	Next-Day Daytime Fatigue	Next-Day Negative Cannabis Consequences	
	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	IRR	Estimate (*SE*)
Fixed Effects							
Level 2 (Between-Person)							
Intercept	1.62 (0.06)***	7.30 (0.12)***	18.95 (2.26)***	15.21 (2.28)***	2.53 (0.08)***	0.03	−3.45 (0.39)***
Cannabis Sleep Aid Use	**−0.46 (0.31)**	**1.49 (0.62)***	**9.60 (12.60)**	**−7.84 (11.55)**	**0.59 (0.45)**	**23.11**	**3.14 (1.29)***
Male Sex	0.12 (0.12)	−0.56 (0.24)*	5.07 (4.79)	−3.76 (4.83)	0.24 (0.17)	2.83	1.14 (0.56)
Age	0.06 (0.05)	0.03 (0.09)	−0.25 (1.87)	−0.00 (1.76)	0.05 (0.07)	0.93	−0.07 (0.21)
Negative Affect	0.05 (0.02)**	−0.09 (0.03)*	0.94 (0.71)	−0.16 (0.70)	0.10 (0.03)***	1.12	0.11 (0.10)
Cannabis Frequency	0.05 (0.07)	−0.20 (0.15)	−5.24 (2.93)	4.72 (2.90)	−0.16 (0.11)	1.77	0.56 (0.35)
Tobacco Frequency	−0.03 (0.03)	0.06 (0.06)	1.00 (1.20)	−1.77 (1.09)	0.01 (0.04)	1.08	0.08 (0.08)
Level 1 (Within-Person)							
Cannabis Sleep Aid Use	**−0.07 (0.14)**	**0.64 (0.31)***	**−1.25 (4.30)**	**−13.74 (4.61)****	**0.34 (0.17)***	**1.37**	**0.32 (0.28)**
Cannabis Sleep Aid Use (Lagged)	**0.07 (0.14)**	**−0.11 (0.31)**	**−1.31 (4.27)**	**4.18 (4.63)**	**0.00 (0.16)**	**0.84**	**−0.17 (0.25)**
Study Days	0.10 (0.07)	0.13 (0.16)	−6.95 (2.71)*	1.98 (4.11)	−0.16 (0.09)	0.39	−0.94 (0.32)**
Weekend (Friday & Saturday)	−0.07 (0.07)	0.13 (0.15)	−3.01 (1.91)	1.11 (2.42)	−0.02 (0.08)	0.70	−0.35 (0.26)
Negative Affect	0.04 (0.01)**	−0.05 (0.03)	0.16 (0.41)	−0.45 (0.54)	0.02 (0.02)	0.94	−0.06 (0.06)
Negative Affect (Lagged)	0.03 (0.01)*	−0.03 (0.03)	0.28 (0.40)	0.10 (0.56)	0.01 (0.02)	1.04	0.04 (0.07)
Cannabis Frequency	−0.03 (0.04)	0.05 (0.08)	−2.57 (1.14)*	0.24 (1.24)	0.01 (0.05)	1.19	0.17 (0.11)
Cannabis Frequency (Lagged)	−0.04 (0.04)	0.10 (0.08)	−0.31 (1.12)	−0.17 (1.22)	−0.01 (0.05)	1.17	0.16 (0.10)
Tobacco Frequency	0.02 (0.06)	0.20 (0.12)	−1.42 (1.67)	0.96 (2.13)	0.15 (0.07)*	0.97	−0.03 (0.08)
Tobacco Frequency (Lagged)	0.08 (0.06)	−0.36 (0.12)**	2.51 (1.67)	−0.17 (1.83)	0.06 (0.07)	1.03	0.03 (0.11)
Random Effects							
Level 2 (Between-Person)							

	Same-Night Poor Sleep Quality Rating	Same-Night Sleep Duration	Same-Night Sleep Onset Latency	Same-Night Waketime After Sleep Onset	Next-Day Daytime Fatigue	Next-Day Negative Cannabis Consequences	
	Estimate (*SE*)	**Estimate (*SE*)**	**Estimate (*SE*)**	**Estimate (*SE*)**	**Estimate (*SE*)**	**IRR**	**Estimate (*SE*)**
Intercept	0.10 (0.03) ***	0.39 (0.12) **	251.20 (47.92) ***	162.89 (45.05) ***	0.26 (0.06) ***	12.47	2.52 (0.82) **
Study Days	-	0.35 (0.25)	322.73 (78.50) ***	681.27 (197.83) ***	-	2.82	1.04 (0.67)
Level 1 (Within-Person)							
Residual	0.71 (0.04) ***	3.16 (0.18) ***	560.62 (30.45) ***	276.54 (31.88) ***	0.87 (0.05) ***		
Autocorrelation	0.12 (0.04) **	0.08 (0.05)	−0.08 (0.05)	0.15 (0.12)	0.19 (0.05) ***		

Note. n=83. Sleep aid use predictors highlighted in bold font. Results of Negative Cannabis Consequences (dispersion parameter=0.00, SE=0.21, p=.99) model is based on negative binomial multilevel models and incidence rate ratios (IRR) are reported. Lagged predictors represent effects on (a) sleep quality rating, duration, onset latency, and wake-time after sleep onset the following day; (b) daytime fatigue and negative alcohol/cannabis consequences two days later.

* p <.05.

** p<.01.

*** p<.001.

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Table 3

Multilevel Models of Daily Alcohol Sleep Aid Use Predicting Sleep- and Substance-Related Outcomes

	Same-Night Poor Sleep Quality Rating	Same-Night Sleep Duration	Same-Night Sleep Onset Latency	Same-Night Waketime After Sleep Onset	Next-Day Daytime Fatigue	Next-Day Negative Alcohol Consequences	
	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)	IRR	Estimate (*SE*)
Fixed Effects							
Level 2 (Between-Person)							
Intercept	1.63 (0.06)***	7.37 (0.12)***	18.568 (2.27)***	14.06 (2.26)***	2.57 (0.08)***	0.07	−2.65 (0.30)***
Alcohol Sleep Aid Use	**−0.99 (1.57)**	**1.68 (3.28)**	**97.91 (64.08)**	**−8.51 (56.78)**	**0.73 (2.31)**	**0.04**	**−3.23 (3.84)**
Male Sex	0.06 (0.12)	−0.60 (0.26)*	6.48 (5.02)	−3.01 (5.05)	0.17 (0.18)	0.83	−0.19 (0.38)
Age	0.06 (0.05)	0.01 (0.10)	−1.82 (1.97)	0.70 (1.87)	0.01 (0.07)	0.99	−0.01 (0.13)
Negative Affect	0.05 (0.02)**	−0.08 (0.04)*	0.90 (0.73)	0.00 (0.69)	0.09 (0.03)***	1.21	0.19 (0.06)**
Alcohol Quantity	0.04 (0.04)	0.00 (0.09)	−1.80 (1.68)	−0.57 (1.72)	0.02 (0.06)	2.17	0.77 (0.13)***
Level 1 (Within-Person)							
Alcohol Sleep Aid Use	**0.66 (0.39)**	**−0.12 (0.84)**	**−1.63 (11.83)**	**−3.25 (13.36)**	**0.62 (0.43)**	**1.73**	**0.55 (0.78)**
Alcohol Sleep Aid Use (Lagged)	**0.05 (0.35)**	**0.18 (0.77)**	**5.98 (10.74)**	**0.52 (9.94)**	**−0.25 (0.40)**	**0.41**	**−0.90 (0.74)**
Study Days	0.12 (0.07)	0.06 (0.15)	−6.05 (2.87)*	2.48 (4.06)	−0.16 (0.09)	0.53	−0.67 (0.31)
Weekend (Friday & Saturday)	−0.17 (0.08)*	0.30 (0.17)	−1.64 (2.38)	1.48 (2.89)	0.01 (0.08)	8.34	2.12 (0.28)***
Negative Affect	0.04 (0.01)**	−0.05 (0.03)	0.36 (0.43)	−0.28 (0.54)	0.02 (0.02)	1.01	0.01 (0.07)
Negative Affect (Lagged)	0.03 (0.01)*	−0.04 (0.03)	0.39 (0.42)	0.15 (0.57)	0.01 (0.02)	0.99	−0.01 (0.07)
Alcohol Quantity	0.04 (0.01)**	−0.06 (0.03)*	−0.97 (0.39)*	−0.39 (0.51)	−0.01 (0.01)	0.89	−0.11 (0.04)**
Alcohol Quantity (Lagged)	−0.02 (0.01)	0.02 (0.03)	−0.05 (0.39)	0.04 (0.47)	0.02 (0.02)	0.87	−0.14 (0.04)**
Random Effects							
Level 2 (Between-Person)							
Intercept	0.10 (0.03)***	0.44 (0.13)***	253.60 (50.13)***	161.93 (45.62)***	0.27 (0.07)***	1.68	0.52 (0.22)
Study Days	-	0.32 (0.25)	346.09 (87.54)***	645.48 (191.89)***	-	3.65	1.29 (0.95)
Level 1 (Within-Person)							
Residual	0.71 (0.04)***	3.24 (0.19)***	609.22 (33.73)***	293.73 (34.23)***	0.89 (0.06)***		

	Same-Night Poor Sleep Quality Rating	Same-Night Sleep Duration	Same-Night Sleep Onset Latency	Same-Night Waketime After Sleep Onset	Next-Day Daytime Fatigue	Next-Day Negative Alcohol Consequences	
	Estimate (*SE*)	**Estimate (*SE*)**	**Estimate (*SE*)**	**Estimate (*SE*)**	**Estimate (*SE*)**	**IRR**	**Estimate (*SE*)**
Autocorrelation	0.15 (0.04)***	0.09 (0.05)*	0.03 (0.05)	0.219 (0.11)	0.21 (0.05)***		

Note. n=83. Sleep aid use predictors highlighted in bold font. Results of Negative Alcohol Consequences (dispersion parameter=3.01, SE=0.93, p=.001) model is based on negative binomial multilevel models and incidence rate ratios (IRR) are reported. Lagged predictors represent effects on (a) sleep quality rating, duration, onset latency, and wake-time after sleep onset the following day; (b) daytime fatigue and negative alcohol/cannabis consequences two days later.

* p<.05.

** p<.01.

*** p<.001.