Published in final edited form as:

Alcohol Clin Exp Res. 2017 April ; 41(4): 798–809. doi:10.1111/acer.13342.

Using Sleep Interventions to Engage and Treat Heavy-Drinking College Students: A Randomized Pilot Study

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Abstract

Background—Continued high alcohol consumption levels by college students highlight the need for more effective alcohol interventions and novel treatment engagement strategies. The purpose of this study was to investigate a behavioral sleep intervention as a means to engage heavy-drinking college students in treatment and reduce alcohol use and alcohol-related consequences.

Methods—Heavy-drinking college students (N=42) were assigned to 1 of 2 web-based interventions comprised of 4 modules delivered over 4 weeks. The experimental intervention focused primarily on sleep and included evidence-based sleep content (i.e., stimulus control instructions, sleep scheduling (consistent bed/rise times; ideal sleep duration for adolescents/young adults), sleep hygiene advice, relaxation training, cognitive strategies to target sleep-disruptive beliefs) and alcohol content (i.e., normative and blood alcohol level feedback, moderate drinking guidelines, controlled drinking strategies, effects of alcohol on sleep and the body, advice to moderate drinking for improved sleep) in young adults. The healthy behaviors control condition provided basic advice about nutrition, exercise, sleep (i.e., good sleep hygiene only) and drinking (i.e., effects of alcohol on the body, moderate drinking guidelines, advice to moderate drinking for sleep). Participants in both conditions monitored their sleep using daily web-based diaries and a wrist-worn sleep tracker.

Results—Recruitment ads targeting college students with sleep concerns effectively identified heavy-drinking students. The program generated a high number of inquiries and treatment completion rates were high. Both interventions significantly reduced typical week drinking and alcohol-related consequences and improved sleep quality and sleep-related impairment ratings. The control condition yielded greater reductions in total drinks in a heaviest drinking week. The effects on drinking were larger than those observed in typical brief alcohol intervention studies for

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Conflict of interest

Drs. Fucito and DeMartini have registered the name and content of the Call it a Night® web-based sleep program with the U. S. Patent and Trademark Office.

college students. Greater sleep improvement tended to predict better subsequent drinking outcomes. The results suggest that sleep treatment may be a promising strategy for targeting and treating heavy-drinking college students.

Keywords

Alcohol; Heavy Drinking; Sleep; College Students; Young Adults

INTRODUCTION

Heavy alcohol consumption among college students is a major public health concern. Nearly half of all college students report at least one past month heavy drinking episode (SAMHSA, 2010). This level of alcohol consumption is associated with greater risk of negative consequences, such as poor academic performance, unwanted/unprotected sex, physical fights, and also with increased injury risk, including motor vehicle accidents, the leading causes of death in this age group (Hingson et al., 2009, Park, 2004, Singleton Jr and Wolfson, 2009, Taylor and Bramoweth, 2010, Wechsler et al., 1994). Compared to their non-college attending peers, college students report comparable typical average quantities of alcohol but are more likely to consume a higher maximum number of drinks (SAMSHA, 2010). College students also have elevated rates of alcohol use disorders (i.e., roughly 20%) (Blanco et al., 2008, SAMHSA, 2010). Though many college students “mature out” of heavy drinking with the responsibilities of adulthood following graduation, a sizeable number persist in their heavy drinking (Jackson et al., 2001).

To address this problem, numerous prior studies have tested alcohol interventions for college students (for reviews, see (Carey et al., 2007, Carey et al., 2009, Carey et al., 2012, Crounce and Larimer, 2011). Interventions often emphasize increasing motivation and commitment to change drinking (Crounce and Larimer, 2011). Common components include education about alcohol, personalized drinking feedback (e.g., students’ drinking patterns, alcohol-related consequences, beliefs about alcohol, and motives for drinking) and specific strategies for reducing alcohol consumption and alcohol-related consequences (Crounce and Larimer, 2011). These interventions are efficacious for reducing alcohol use and alcohol-related consequences, but the effects are typically small (Carey et al., 2007, Crounce and Larimer, 2011). Moreover, interventions tend to be less effective for the heaviest drinkers and other high-risk students (e.g., members of fraternities/sororities) (Carey et al., 2007).

The most effective alcohol interventions are individual, face-to-face interventions that incorporate motivational interviewing techniques and personalized, normative feedback about alcohol use (Carey et al., 2007), but this modality is costly, time-intensive, and not practical in all college settings (Carey et al., 2012, Nelson et al., 2010). Computer-based and web-based alcohol interventions provide a promising alternative. These interventions have comparable effects on drinking (Carey et al., 2012), and college students prefer them over face-to-face interventions (Epler et al., 2009, Buscemi et al., 2010). Additional advantages of computer- and web-based interventions include convenience, reduced cost, privacy, ease-of-dissemination, and standardization of content (Leeman et al., 2015). Because of these

numerous benefits, computer- and web-based interventions may be particularly beneficial for early intervention (Carey et al., 2012).

Although efficacious interventions have been identified, delivering them to college students remains a challenge. Most college students are not motivated to change their drinking (Black and Coster, 1996, Epler et al., 2009), and consequently, do not seek services to help them with their drinking (Buscemi et al., 2010). College students are, however, open to health interventions, such as sleep treatment (Fucito et al., 2015, Orzech et al., 2011). One key component of behavioral sleep interventions involves targeting sleep-disruptive behaviors like alcohol consumption (Stepanski and Wyatt, 2003). Expanding the alcohol-specific content in a sleep or general health intervention to include efficacious alcohol intervention components, such as personalized feedback, moderate drinking recommendations, and drinking reduction strategies may effectively target alcohol consumption without reliance on self-identification for specialty alcohol treatment.

Sleep may, therefore, serve as a “gateway” health topic for addressing alcohol use among college students, but there may be other benefits to addressing sleep problems in this population. Sleep problems are common among college students, some of which may be attributable to their alcohol use (DeMartini and Fucito, 2014). Alcohol has well-documented negative effects on multiple sleep indices (Ebrahim et al., 2013). Among college students, higher alcohol use is associated with lower sleep duration, greater sleep schedule irregularity, bedtime delay, weekend oversleeping, and sleep-related impairment (DeMartini and Fucito, 2014, Singleton Jr and Wolfson, 2009). Conversely, poor sleep may increase risk of heavy drinking and alcohol-related harm among college students. For example, sleep problems in adolescence predict earlier onset and greater risk of an alcohol use disorder and greater risk of heavy-drinking and alcohol-related problems in young adulthood (Breslau et al., 1996, Hasler et al., 2016, Wong et al., 2015). Further, young adults with poor sleep experience greater consequences from drinking than their counterparts who drink but report good sleep (DeMartini and Fucito, 2014, Kenney et al., 2012, Miller et al., 2016). Thus, the additional benefits of implementing sleep interventions for heavy-drinking college students may include reducing alcohol use and alcohol-related consequences. This hypothesis, however, has not been tested.

Efficacious sleep interventions for college students include education about sleep stages and circadian rhythms, good sleep hygiene, strategies to create a sleep-conducive environment, instructions for time in bed, and/or relaxation/mindfulness techniques for stress-management (Brown et al., 2006, Kloss et al., 2011; Trockel et al., 2011). Some interventions also include cognitive strategies to reduce maladaptive sleep beliefs (Brown et al., 2002, Gellis et al., 2013, Trockel et al., 2011). Sleep interventions have medium to large effects on sleep quality and important sleep correlates (e.g., depressive symptoms) among college students (Brown et al., 2002, Kloss et al., 2011) and are effective when computer-based (Trockel et al., 2011) or delivered in brief formats (Gellis et al., 2013). Simple sleep hygiene education (i.e., advice about good sleep habits and practices) may briefly address limiting alcohol use before bedtime (Stepanski and Wyatt, 2003); however, this information alone has not been shown to be effective in reducing heavy alcohol use. Adding an evidence-based alcohol

intervention to sleep treatment for college students might promote greater reductions in drinking.

The study had two goals. First, we investigated the feasibility of using sleep concerns as a possible gateway to engaging heavy-drinking college students into alcohol treatment. Second, we examined the acceptability, feasibility, and preliminary efficacy of a web-based integrated sleep and alcohol intervention for college students compared with a matched healthy behaviors control condition. Intervention development was based on the results of our prior qualitative research with heavy-drinking college students (Fucito et al., 2015). The primary outcomes were changes in alcohol use and alcohol-related consequences and self-report ratings of sleep quality and sleep-related impairment. Secondary outcomes included changes in objective sleep characteristics (i.e., duration, bedtime and rise time).

METHODS

Design

This study was a two-condition, randomized controlled pilot study conducted with treatment-seeking college students who reported sleep concerns and heavy alcohol consumption. Participants were randomized to 1 of 2 web-based behavioral interventions comprised of 4 modules delivered over 4 weeks: (1) an experimental intervention that focused primarily on sleep and included evidence-based content for improving sleep and drinking in young adults - “Call it a Night®” (CIAN) or (2) a matched attention-control intervention – “Healthy Behaviors” (HB) – that provided basic advice about nutrition, exercise, sleep, and drinking. A sample size of 42 was selected for this pilot study to allow for approximately 20 participants per condition to test feasibility and acceptability of the intervention conditions and preliminary effects on alcohol and sleep outcomes. Randomization was stratified by sex using an allocation sequence established before study enrollment began by a statistician with no participant contact. A research staff member not affiliated with the study then prepared sequentially numbered envelopes with condition assignment for both men and women. At the time of randomization, the RA opened the envelope that corresponded to the next allocation sequence to randomize participants. The Institutional Review Board of Yale School of Medicine approved this trial.

Participants

To be eligible, participants had to report the following: (1) concerns about sleep (dichotomous: yes/no), (2) 1 heavy drinking occasion(s) in the past month (i.e., 5 drinks on 1 occasion for men; 4 for women), (3) risk of harm from drinking based on an AUDIT-C (Bush et al., 1998) of 7 for men; 5 for women), and (4) current enrollment as an undergraduate student.

Procedures

College students were recruited and randomized at two time points (i.e., March-April 2015 and October-November 2015) from five local colleges in New England primarily through advertisements on Facebook, flyers posted around campuses, and announcements emailed to college administrators/faculty. Advertisements, which ran for 2 months in the Spring

semester and 1 month in the Fall semester, targeted college students with sleep problems and stated that the purpose of the study was to test a new sleep intervention. The last follow-up was completed in April 2016.

Interested volunteers who clicked on web-based advertisements or contacted study staff were first directed to the study website to complete a web-based pre-screener that took approximately 5 minutes. Individuals who met initial eligibility were then invited to participate in an in-person intake appointment of approximately 45–60 minutes, to verify final eligibility and assess demographic information and sleep and drinking characteristics.

Eligible participants were then assigned to one week of sleep monitoring that entailed completing daily web-based sleep diaries and wearing a sleep tracker to obtain a comprehensive baseline sleep assessment prior to the intervention (see Figure 1 for a participant timeline). To encourage adherence with sleep-monitoring activities, participants received daily reminder emails. Participants were also informed that they would be compensated (\$2) for each diary completion; they would also receive a bonus for completing the full week of diaries (\$10) and compensation for returning the sleep tracker (\$15).

Participants returned for an in-person visit at the end of the one-week baseline monitoring period (i.e., Week 1) to complete in-person assessments and return their sleep tracker. If applicable based on adherence, participants were then randomly assigned to either the CIAN or HB intervention based on a preset computer-generated randomization schedule. Participants were blind to condition assignment. They received login instructions for accessing a study website. Participants were asked to log onto the website while at the research suite to ensure they could access it.

The treatment period of the study lasted for 4 weeks. During this time, participants were instructed to log-on to the study website to access treatment information as often as they liked. Each treatment condition included 4 modules. The first module was available at the time of randomization. At the end of 1 week, a new treatment module was unlocked for participants to access. By Week 4, all modules were available to participants. Participants received reminder emails when new modules became available.

Participants returned for an in-person visit at Week 4 to complete in-person assessments and pick up a sleep tracker for Week 4 sleep monitoring. Participants resumed sleep monitoring activities (i.e., completing daily diaries and wearing a sleep tracker) during the last week of treatment. At treatment completion and the end of sleep monitoring (i.e. Week 5), participants returned for an in-person visit to complete research assessments and return the sleep tracker. Three months after completing treatment, participants completed a brief, web-based follow-up assessment.

Intervention Conditions

To design an integrated sleep and alcohol intervention for college students, “Call it a Night®”, we conducted focus group interviews with heavy-drinking college students to assess their perceptions of sleep and alcohol/sleep interactions and their behavioral health treatment preferences (Fucito et al., 2015). After the first round of interviews, we designed

an initial beta model of the intervention. Intervention content was adapted from multiple sources including: (1) evidence-based brief alcohol interventions and evidence based strategies for promoting better sleep in college students (Brown et al., 2002, Brown et al., 2006, Carey et al., 2007, Carey et al., 2009, Carey et al., 2012, Crouce and Larimer, 2011, Gellis et al., 2013, Trockel et al., 2011), (2) an evidence-based website focused on sleep and health education (i.e., Division of Sleep Medicine, Harvard Medical School) (Harvard Medical School, 2009), an empirically supported, web-based sleep treatment program (i.e., Shut-I) (Christensen et al., 2016), and (4) research studies documenting the effects of alcohol and drugs on sleep and the potential synergistic effects of poor sleep and drinking on health and functioning (Ebrahim et al., 2013, Kenney et al., 2012, Miller et al., 2016, Banks et al., 2004, Brumback et al., 2007). All of this health information was tailored for college students. We then conducted a second round of focus group interviews with a new group of college students who were shown a beta version of the intervention using PowerPoint. We used this second round of feedback to finalize the intervention (see Table 2 for a description of the CIAN intervention condition). The intervention, comprised of 4 modules, was designed to be 4 weeks in length and a passive intervention, due to budget constraints. The intervention delivered new health information modules each week. At the beginning of each module, participants received a brief, personalized summary of their health information (e.g., qualitative sleep characteristics, alcohol use) using data obtained from the intake assessments. Sleep advice, however, was not personalized to participants' specific sleep characteristics. Participants received general sleep advice that included stimulus control (i.e., limit activities in bed, time awake in bed), the recommendation to maintain a consistent bed/rise time and sleep duration of 8–9 hours based on recommendations for adolescents/young adults, information about common behaviors (e.g., alcohol) and environmental factors that disrupt sleep and how to address them, and tips for managing stress.

For the control condition, “Healthy Behaviors,” we selected alcohol and sleep content that are less effective for improving these outcomes in college students as well as basic health information (see Table 2 for a description of the HB intervention condition). Our goals for this condition were to include enough information to keep students engaged and to maximize the face validity of the condition by including some basic sleep information and advice that good general health practices were helpful for sleep. The intervention was comprised of 4 modules delivered over 4 weeks. It was also a passive intervention that delivered new content each week. Participants did not receive personalized feedback about their health information at the beginning of each module. Further, the health information provided had minimal tailoring for college students. The two conditions were not matched for length. The CIAN condition had a larger total number of webpages than the HB condition. Another major difference was that good sleep hygiene advice, including advice to limit alcohol use for better sleep, was provided all at once in the first module of the HB condition but broken up into different sections across all 4 modules of the CIAN condition to allow for more in-depth coverage.

A technology partner, MEA Mobile, helped finalize the design and development of both web-based interventions. The final password-protected websites were hosted on a secure Yale server.

Measures

Interested participants completed a computer-based pre-screening to provide an initial assessment of eligibility. All questionnaires were computer-based.

Alcohol Use and Consequences—The Alcohol Use Disorders Identification Test (AUDIT) is a brief, standardized screener for hazardous drinking and alcohol use disorders (Bush et al., 1998). Scores on the AUDIT Consumption Subscale (AUDIT-C) of 7 and 5 for men and women, respectively, have been identified as optimal cut-off scores for identifying at-risk drinking in college students (Demartini and Carey, 2009). The AUDIT was assessed at intake to verify eligibility.

The Daily Drinking Questionnaire (DDQ) (Collins et al., 1985) assessed alcohol use starting 30 days prior to and including the assessment day to verify eligibility (i.e., at least 1 occasion of heavy drinking in the last 30 days). A 7-day grid was used to assess primary drinking outcomes - typical week drinking and heaviest week drinking based on the following standard drink definition: 12-oz. beer, 5-oz. of wine, or 1.5-oz. of hard liquor (straight or in a mixed drink), all equivalent to approximately 0.6oz. or 14g of pure alcohol (NIAAA, 2010). The DDQ was assessed at intake, Week 5 treatment completion, and 3-month follow-up.

The Brief Young Adult Alcohol Consequences Questionnaire (BYAACQ) is a 24-item self-report assessment of alcohol-related consequences in the past 30 days (Kahler et al., 2005). Items are tailored for a collegiate population and include driving while intoxicated, unplanned sexual activity, and blacking out. Items were summed to create a total number of consequences score for each participant. The BYAACQ was assessed at intake, Week 5, and 3-months.

Subjective Ratings of Sleep Quality and Sleep-Related Impairment—For the internet-based pre-screener, potential participants indicated whether they had any concerns about their sleep using a dichotomous variable (1=yes, 0=no) and then rated the severity of their sleep concerns on a 10-point scale with higher scores indicative of greater concerns.

The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989), a 19-item measure, was used to assess total self-reported sleep disturbance using the global PSQI score. The PSQI is a reliable, valid tool for detecting “good” versus “poor” sleepers. Suggested cut-off scores for the total PSQI include 5 and 7 with higher scores indicating poorer self-reported sleep (Buysse et al., 1989). The PSQI was assessed at intake, Week 5, and 3 months.

The 8-item NIH Patient Reported Outcomes Measurement Information System Sleep-Related Impairment Short-Form (PROMIS-SRI-SF) (Yu et al., 2011), a reliable, precise measure that allows for normative comparisons, assessed qualitative aspects of sleep-wake function (e.g., perceptions of sleepiness, functional impairments due to sleep problems) using the total score. Raw total scores were converted into standardized scores using a T score with a mean score of 50 and standard deviation of 10. The PROMIS-SRI-SF was assessed at intake, Week 5, and 3 months.

The **Pittsburgh Sleep Diary** assessed daytime sleep-related behaviors and nocturnal sleep characteristics.(Monk et al., 1994) Participants were instructed to complete daily web-based diaries in the mornings to track daytime sleep-related behaviors and nocturnal sleep characteristics of the preceding day the week before randomization and the last week of treatment (i.e., Week 4). Diaries assessed daytime behaviors related to sleep (e.g., number of drinks consumed before bedtime) as well as ratings of sleepiness upon waking. Participants were informed at the intake appointment that they needed to demonstrate adequate diary adherence (i.e., completing at least 75% of the diaries) to be randomized for the intervention portion of the study. The Pittsburgh Sleep Diary was assessed at intake, Week 5, and 3 months.

Objective Quantitative Sleep Characteristics—To measure objective quantitative sleep characteristics, participants wore Philips Respironics Actiwatch 2 actigraphy devices, well-validated wrist-worn sleep trackers that measure sleep/wake activity. Participants were instructed to wear the sleep trackers continuously (except while bathing and swimming) on their non-dominant wrist the week before randomization and the last week of treatment (i.e., Week 4). They were instructed to depress the event marker when ready to initiate sleep after getting into bed. They were also instructed to depress the event marker immediately upon waking to indicate the end of the sleep episode. Participants were also asked to record all the times when they removed the device in the diary.

Actigraphy is a valid, reliable methodology to objectively estimate sleep based on measuring activity and inactivity (Littner, 2003). Actigraphy is sensitive to changes over time and interventions (Littner, 2003). Actigraphy data were collected in 15 second epochs, a high sensitivity setting. Participants were informed at the intake appointment that they needed to demonstrate adequate actigraphy adherence (i.e., wearing the device for at least 75% of the time) to be randomized for the intervention portion of the study.

Actigraphy data was scored using the Philips Respironics Actiwatch2 scoring software. The event markers were used to identify the major sleep periods. In the event that the event marker was not used, diary reports of lights out and lights on times were used to determine the sleep period. To optimize scoring accuracy, two study authors (TH and LF) compared the sleep scoring output against sleep diary data including participants' records of ever having removed the devices. Off-wrist periods were manually set to missing by the authors. Any periods of daytime inactivity that were scored as sleep but conflicted with participants' diary data were also corrected. This correction was only applied in a few cases.

The following sleep outcomes were derived from the Actiwatch2 scoring software and evaluated over time by condition: (1) bed time (i.e., time of sleep initiation), (2) rise time (i.e., time of waking), (3) sleep duration (i.e., total time between sleep initiation and waking), and (4) sleep efficiency.

Treatment Adherence—Google analytics was used to track participant access and page views for both websites. Treatment completion was defined as meeting two criteria: (1) accessing all 4 modules at least once and (2) across all 4 modules, accessing at least 80% of the webpages.

Data Analysis

T-tests and Fisher's exact tests were used to evaluate potential baseline differences by condition on demographic variables. Fisher's exact tests were used to compare the likelihood of completing treatment by condition and the likelihood of suggesting improvements for treatment. Analyses of variance (ANOVAs) were used to compare conditions on treatment satisfaction ratings and usage among the subsample of treatment completers (n=38). Primary outcome analyses fit generalized estimating equations (GEE) for key variables. GEE models were selected due to their ability to provide consistent parameter estimates even in small-scale studies; they are less sensitive to any covariance structure misspecification than generalized linear mixed models. GEEs were fit to examine changes in alcohol (i.e., total drinks and alcohol-related consequences) and subjective sleep outcomes (i.e., ratings of sleep quality and sleep-related impairment) from intake (Time 1) to treatment completion at Week 5 (Time 2) to follow-up at 3-months (Time 3). Models for objective sleep outcomes (i.e., actigraphy data on sleep duration, bed/rise times, sleep efficiency) only included two time points: intake (Time 1) and treatment completion at Week 5 (Time 2). GEE model fixed effects were: time, condition (CIAN vs. HB), and sex (a stratification variable). Models included all 2-way interaction terms and a 3-way interaction term of Condition $\times$ Time $\times$ Sex and subject as a random factor. A negative binomial with log link distribution was used for models testing total drinks in a typical and heaviest drinking week that were both positively skewed. GEE models included the full sample of randomized participants and used all available data per participant. If the GEE model identified a significant effect of condition, sex, and/or time (i.e., based on a significant Wald chi-square test), a Bonferroni-corrected post hoc test was then conducted to examine the effect. This post hoc, multiple-comparison correction controls the family-wise, Type I error rate across simultaneous post hoc tests. They yield a comparison of estimated mean differences by a given fixed effect (e.g., condition), a 95% confidence interval of the estimated mean difference, and an alpha level adjusted for these multiple comparisons. Effect sizes for the difference in drinking and sleep outcomes from intake to 3 months were calculated as the mean differences between the CIAN and HB conditions divided by the pooled standard deviation (Cohen, 1998). A Hedges' correction corrected for sample size bias (Hedges, 1981). We also conducted an exploratory analysis of sleep improvement from intake to Week 5 as a predictor of drinking outcomes at 3 months among participants with complete follow-up data (n=38) using generalized linear models.

RESULTS

Feasibility of Using Sleep Concerns to Enroll Heavy-Drinking College Students in Alcohol Treatment

Study ads generated a high number of inquiries. Of the 406 potential participants who completed web-based pre-screening, 49 were invited for an in-person intake appointment. Of these individuals, 6 were excluded for not meeting final eligibility criteria or complying with baseline sleep monitoring activities and 1 chose not to enroll (see Consort Figure 2). Forty-two undergraduate students (22 men; 20 women) were randomized to either: CIAN (n = 21) or HB (n = 21) and completed at least the first treatment module. Thirty-eight participants completed the end of treatment and research follow-up appointments at 3-months. The

baseline characteristics of all randomized participants are displayed in Table 1. The two conditions were equivalent at baseline on all demographic, drinking, and sleep variables except for sleep-related impairment. HB participants reported significantly greater sleep-related impairment than CIAN participants [$t(40) = 2.13, p = .04$] (see Table 3).

Sleep Intervention Feasibility and Acceptability

Nearly all participants (88%) accessed all 4 treatment modules at least once. Five participants did not access all 4 modules (CIAN = 2; HB = 3). Likewise, most participants (79%) accessed at least 80% of the webpages across all 4 modules; nine participants did not access at least 80% of the content (CIAN = 5; HB = 4). Thus, based on these two criteria, 33 participants were coded as treatment completers. Treatment completers differed from non-completers on several demographic and clinical characteristics. Treatment completers were more likely to be women [Fisher's Exact Test = .02], reported consuming fewer drinks in a heaviest drinking week [$M = 21.85, SE = 3.89$ vs. $M = 49.67, SE = 16.72$; $Wald \chi^2(1) = 4.65, p = .03$], and scored lower on the AUDIT-C [$M = 6.91, SD = 1.68$ vs. $M = 8.44, SD = 1.42$; $t(40) = 2.50, p = .02$]. Treatment completers did not differ from non-completers on subjective or objective sleep characteristics.

There were no adverse events. Overall treatment satisfaction ratings were moderately positive and did not differ by condition (see Table 2). Participants in both conditions rated treatment as very easy to understand but rated the enjoyment of using the interventions as more moderate. Participants in both conditions spent a similar amount of time and had similar suggestions for improvement, the most common of which were to make the interventions more personalized and interactive.

Sleep Intervention Preliminary Efficacy

Alcohol Use—As shown in Table 3, there were significant effects of sex [$Wald \chi^2(1) = 4.70, p = .030$] and time [$Wald \chi^2(2) = 24.38, p < .001$] and a significant interaction of sex and time [$Wald \chi^2(2) = 13.55, p = .001$] on total number of drinks consumed in a typical week. There was no effect of treatment condition [$Wald \chi^2(1) = .69, p = .41$]. Significant model effects were then further examined using Bonferroni-corrected post hoc tests. Overall, women [$M = 11.44, SE = 1.31$] reported fewer total drinks than men [$M = 16.67, SE = 2.18$; $M_{diff} = 5.23, 95\% \text{ CI } (.25, 10.21), p = .04$]. Across time, the Week 5 [$M = 14.92, SE = 1.24$] and 3-month follow-up estimates [$M = 9.77, SE = 1.36$] were significantly lower than at intake [$M = 18.05, SE = 1.63$; $M_{diff} = 3.13, 95\% \text{ CI } (.93, 5.33), p = .002$; $M_{diff} = 8.28, 95\% \text{ CI } (4.25, 12.31), p < .001$]. The 3-month estimate was also significantly lower than the Week 5 estimate [$M_{diff} = 5.15, 95\% \text{ CI } (2.05, 8.25), p < .001$]. Thus, typical week drinking quantity decreased from intake to follow-up, regardless of condition. The estimated effect size was in the medium range for both conditions. Women's typical drinking did not reduce from intake during treatment [$M_{diff} = .33, p = 1.00$] but reduced by 3-months [$M_{diff} = 6.60, 95\% \text{ CI } (3.01, 10.19), p < .001$]. In contrast, men's typical week drinking reduced during treatment [$M_{diff} = 6.89, 95\% \text{ CI } (1.13, 12.64), p = .007$] but did not remain reduced at 3-months [$M_{diff} = 10.39, 95\% \text{ CI } (-.77, 21.55), p = .10$].

For total number of drinks consumed in a heaviest drinking week, there were significant main effects of sex [$Wald \chi^2(1) = 4.76, p = .03$] and time [$Wald \chi^2(2) = 28.12, p < .001$] and significant interactions of treatment condition and time [$Wald \chi^2(2) = 7.39, p = .03$] and sex and time [$Wald \chi^2(2) = 6.58, p = .04$]. Bonferroni-corrected post hoc tests demonstrated that women [$M = 16.26, SE = 0.10$] reported a significantly lower total drinks in a heaviest drinking week than men [$M = 25.43, SE = 3.74; M_{diff} = 9.17, 95\% CI (.54, 17.80), p = .04$]. Across time, the Week 5 [$M = 21.32, SE = 2.38$] and 3-month follow-up estimates [$M = 15.05, SE = 2.12$] were significantly lower than the intake estimate [$M = 26.20, SE = 2.56; M_{diff} = 4.88, 95\% CI (1.87, 7.88), p < .001; M_{diff} = 11.15, 95\% CI (5.71, 16.59), p < .001$]. The 3-month estimate was also significantly lower than the Week 5 estimate [$M_{diff} = 6.28, 95\% CI (1.36, 11.19), p = .007$]. Total drinks in the heaviest drinking week reduced significantly over time in the HB condition but not the CIAN condition. Across time, the Week 5 [$M = 18.01, SE = 1.91$] and 3-month follow-up estimates [$M = 11.10, SE = 2.17$] were significantly lower than the intake estimate among HB participants [$M = 24.96, SE = 2.80; M_{diff} = 6.95, 95\% CI (1.38, 12.51), p = .004; M_{diff} = 13.86, 95\% CI (4.27, 23.45), p < .001$] but not CIAN participants [$M_{diff} = 2.26, p = 1.00; M_{diff} = 7.10, p = .09$]. The 3-month estimate was also significantly lower than the Week 5 estimate [$M_{diff} = 6.91, 95\% CI (.06, 13.76), p = .046$] among HB participants but not CIAN participants [$M_{diff} = 4.84, p = 1.00$]. Estimated effect sizes were in the small range for the CIAN condition and the medium range for the HB condition.

Women's drinking in a heaviest drinking week did not decrease from intake during treatment [$M_{diff} = 1.26, p = 1.00$] but reduced after treatment completion. The estimate at 3-months was significantly lower than the intake [$M_{diff} = 7.53, 95\% CI (3.40, 11.66), p < .001$] and Week 5 estimates [$M_{diff} = 6.27, 95\% CI (1.82, 10.72), p < .001$]. In contrast, men's total drinks in a heaviest drinking week reduced from intake during treatment [$M_{diff} = 10.25, 95\% CI (2.26, 18.24), p = .002$] and remained reduced at 3-months [$M_{diff} = 16.27, 95\% CI (.17, 32.37), p = .045$].

Alcohol-Related Consequences—There was a significant main effect of time on alcohol-related consequences [$Wald \chi^2(2) = 76.38, p < .001$] but no effects of sex [$Wald \chi^2(1) = 1.14, p = .29$] or treatment condition [$Wald \chi^2(1) = .66, p = .42$]. Bonferroni-corrected post hoc tests demonstrated across time that the 3-month estimate [$M = 8.24, SE = .58$] was significantly lower than the Week 5 [$M = 10.22, SE = .64; M_{diff} = 1.97, 95\% CI (.47, 3.48), p = .005$] and intake estimates [$M = 16.51, SE = .68; M_{diff} = 8.27, 95\% CI (5.88, 10.66), p < .001$]. The Week 5 estimate was also significantly lower than the intake estimate [$M_{diff} = 6.29, 95\% CI (3.52, 9.06), p < .001$]. Estimated effect sizes for both conditions were in the large range. Thus, alcohol-related consequences decreased from intake to the end of treatment and this reduction was sustained post-treatment, but there was no statistically significant effect of condition.

Subjective Sleep Characteristics—There was a significant effect of time on overall sleep quality [$Wald \chi^2(2) = 75.91, p < .001$] but no effects of sex [$Wald \chi^2(1) = .51, p = .48$] or treatment condition [$Wald \chi^2(1) = 1.25, p = .26$]. Bonferroni-corrected post hoc tests showed that across time, the 3-month estimate [$M = 8.22, SE = 0.36$] was significantly

reduced indicating better sleep quality than the intake estimate [$M = 11.79$, $SE = 0.35$; $M_{diff} = 3.57$, 95% CI (2.56, 4.58), $p < .001$] and the Week 5 estimate [$M = 10.49$, $SE = 0.31$; $M_{diff} = 2.27$, 95% CI (1.44, 3.10), $p < .001$]. Further, the Week 5 estimate was significantly lower than the intake estimate indicating improved sleep quality [$M_{diff} = 1.30$, 95% CI (.44, 2.17), $p = .001$]. The same pattern of findings was observed for ratings of sleep-related impairment. There was a significant main effect of time [$Wald \chi^2(2) = 52.64$, $p < .001$] that was examined using Bonferroni-corrected post hoc tests. The 3-month follow-up estimate [$M = 50.71$, $SE = 1.32$] was significantly lower than the intake [$M = 62.96$, $SE = 1.09$; $M_{diff} = 12.25$, 95% CI (8.21, 16.29), $p < .001$] and Week 5 estimates [$M = 55.74$, $SE = 1.15$; $M_{diff} = 5.02$, 95% CI (1.75, 8.30), $p = .001$] indicating less sleep-related impairment. The Week 5 estimate was also significantly lower than the intake estimate [$M_{diff} = 7.23$, 95% CI (3.50, 10.95), $p < .001$]. The estimated effect size for improvements over time in sleep quality and sleep-related impairment were in the large range for both conditions. Thus, both overall sleep quality and sleep-related impairment improved during treatment and these improvements were sustained through follow-up, regardless of condition.

Objective Sleep Characteristics—There were no significant effects of condition or time on average sleep duration, bedtime, rise time, or sleep efficiency measured using actigraphy [all p 's $> .10$]. There was a significant effect of sex on sleep duration [$Wald \chi^2(1) = .51$, $p = .48$] and bedtime [$Wald \chi^2(1) = 5.06$, $p = .03$] that were examined using Bonferroni-corrected post hoc tests. Women reported significantly longer sleep duration [$M = 6.78$, $SE = .14$] and earlier bed times [$M = 1:24$, $SE = 0:13$] than men [$M = 6.28$, $SE = .14$; $M_{diff} = .50$, 95% CI (.09, .91), $p = .02$; $M = 2:05\text{AM}$, $SE = 0:12$, $M_{diff} = 0:41$, 95% CI (0:05, 1:17), $p = .03$].

Subjective Sleep Changes as a Predictor of Subsequent Drinking—Greater reductions in ratings of daytime impairment from poor sleep during treatment did not significantly predict less drinking in a heaviest drinking week at follow-up [$b = -.04$, 95% CI (-.08, .003), $SE = .02$; $Wald \chi^2(1) = 3.27$, $p = .07$]. Though this result was not statistically significant, the effect size was in the medium to large range [$d = .61$]. No other potential associations between treatment changes in subjective ratings of sleep-related impairment and/or sleep quality and drinking outcomes at follow-up were identified [all p 's $> .10$].

DISCUSSION

The purpose of this study was to investigate sleep treatment as a novel strategy for targeting and treating heavy alcohol use and alcohol-related consequences in college students. It represents an extension of our prior qualitative research focused on heavy-drinking college students' perceptions of sleep interventions and integrated sleep and alcohol treatment models (Fucito et al., 2015). The results suggest that sleep was an effective gateway topic for engaging heavy-drinking college students. In only three months of advertising, the program generated a number of inquiries with over four hundred students completing the web-based pre-screener.

Contrary to expectations, participants in both interventions exhibited medium to large improvements in typical drinking, alcohol-related consequences, and ratings of sleep quality and sleep-related impairment, but there were no time or treatment-related effects on objective sleep characteristics. Likewise, the control condition yielded greater reductions in total drinking in a heaviest week over time than the anticipated experimental condition. Despite these unexpected results, the reductions in drinking and consequences in both conditions are larger compared to the results observed in other brief alcohol intervention studies for college students (Carey et al., 2007; Leeman et al., 2015).

Several factors may account for the unexpected findings in this study. Participants in both conditions received brief sleep hygiene advice and advice to moderate their drinking for improved sleep. This brief advice alone may have been sufficient to improve sleep and reduce drinking. In addition, participants in both conditions actively monitored their sleep and alcohol use before bedtime and completed repeated assessments of both behaviors. Self-monitoring alone is effective for improving sleep quality in college students (Mairs and Mullan, 2015) and reducing alcohol use among individuals who report heavy alcohol use (Helzer et al., 2002, Miller and Wilbourne, 2002). Further, repeated alcohol assessments can reduce college students' drinking (Carey et al., 2006, Hester et al., 2012, McCambridge and Day, 2008, Walters et al., 2007). In order to verify that sleep and alcohol outcomes would not have changed over time in the absence of these interventions, a follow-up study is needed that includes a waitlist control condition, and/or conditions that do not involve regular tracking of sleep and drinking behavior, and/or research assessments that are delayed (Hester et al., 2012). These alternate designs would provide a clearer test of intervention component efficacy and would clarify what level of sleep and/or alcohol improvement would be expected over time without any intervention.

Other possibilities may account for the greater effect of the control condition on heaviest week drinking. The control condition provided all sleep hygiene advice in the first module including the recommendation to limit alcohol use for better sleep. Though the experimental condition provided more comprehensive advice about limiting alcohol use in the second module as well as evidence-based content for reducing alcohol use, providing brief advice to limit alcohol use for sleep earlier in the control condition may have accounted for the larger improvements in heaviest drinking in this condition. Likewise, providing all of the sleep hygiene advice content at once in the control condition may have maximized its efficacy on sleep compared to breaking it up across all 4 modules in the experimental condition. The control condition may have also facilitated better access to alcohol-related information, (i.e., recommendations about moderate drinking) compared to the experimental condition. The control condition contained alcohol-related content that has not been shown to be effective for reducing college student drinking compared to the alcohol-related content in the experimental condition. Nevertheless, the control condition was briefer overall and may have increased participants' chances of seeing the information if they accessed most of the webpages. In contrast, the experimental condition had more content overall thereby increasing the chance that participants may have missed the information if they did not access most of the webpages. This hypothesis is supported by qualitative feedback we received from participants about the two interventions. A primary criticism of the

experimental condition was that the content was too dense in terms of quantity and presentation.

A challenge of mobile health interventions is to match technology usability with the user's needs and expectations (Kaufman et al., 2006, Kushniruk, 2002). Problems can arise when there is a mismatch. Young adults are experienced technology users and have great access to mobile health information (Kwan et al., 2010). Thus, college students may require more sophisticated and innovative strategies to engage them and keep them engaged using a given mobile health intervention (Kwan et al., 2013, Skinner et al., 2006). In this study, participants spent only 20 minutes on average accessing the modules. In addition to dense content, participants' use may have been limited by other factors. For example, another common critique was that the interventions should be more interactive and tailored to their specific health needs. Call it a Night® and the control condition were designed to be passive interventions due to limited financial resources. Future studies with more funding should investigate interactive features as well as strategies for providing feedback about sleep and the interaction between sleep and alcohol use.

Potential study limitations should be noted. We studied a small sample of New England college students whose clinical characteristics and reactions to sleep interventions may not be representative of all heavy-drinking college students. We did not include an assessment only or no self-monitoring control condition and some alcohol and sleep content was common across conditions. Call it a Night® sleep advice was not personalized to participants' sleep characteristics which may have limited its potential impact on objective sleep outcomes. Further, the conditions were not completely matched on content length. The high sensitivity actigraphy setting may have influenced the ability to detect differences by condition. Though there is limited research on the use of different actigraphy settings, the results of at least one study suggest that the high sensitivity setting successfully detects sleep but is less accurate in detecting wake (Kushida et al., 2001). The findings should be interpreted with caution given the small sample size.

Despite these limitations, this study represents the first test to our knowledge of a sleep intervention for engaging heavy-drinking college students in alcohol treatment and reducing alcohol and alcohol-related consequences. Specifically, sleep self-monitoring and brief sleep advice may be effective strategies for reducing drinking among college students. This novel line of research warrants further investigation.

Acknowledgments

We would like to thank Stephanie O'Malley, Ph.D. and Kassondra Bertulis, B.A. for their assistance with study design and implementation.

Financial support

This research was supported by grants from the National Institutes of Health: K23AA020000 (LMF), P20NR014126 (NSR), T32AA015496 (KSD) and by the State of Connecticut, Department of Mental Health and Addiction Services.

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Figure 1.
Participant Timeline

Figure 2.
Consort Diagram

Table 1

Pretreatment characteristics of randomized participants by condition (N = 42)

Characteristics	Call it a Night® (n = 21)	Healthy Behaviors (n = 21)
Sex, n (%)		
Men	11 (52)	11 (52)
Women	10 (48)	10 (48)
Age, M (SD)	20.71 (1.42)	20.33 (1.20)
Race, n (%)		
Caucasian	12 (57)	16 (76)
African American	1 (5)	1 (5)
Asian	5 (24)	2 (10)
Other	3 (14)	2 (9)
Class, n (%)		
Freshmen	2 (10)	1 (5)
Sophomore	6 (29)	7 (33)
Junior	3 (14)	4 (19)
Senior	10 (48)	9 (43)

Table 2

Comparison of intervention conditions

	Call it a Night®	Healthy Behaviors
Module 1	<ul style="list-style-type: none"> • Effects of poor sleep on health, cognition, and performance • Sleep physiology and circadian rhythms • Sleep duration recommendation of 8–9 hours • Sleep stimulus control strategies tailored to college students <ul style="list-style-type: none"> – Limit bed/bedroom activity to sleep & sex; sit at edge of bed, perpendicular to headboard if have to study/work in bed – Keep consistent bed/rise time – Limit time in bed awake to 20–30 min before going to bed & upon waking – Get out of bed if awake > 20–30 minutes; tips for handling being awake • Sleep hygiene education tailored to college students – specific sleep habits <ul style="list-style-type: none"> – Limit naps – Establish a pre-bedtime sleep routine 	<ul style="list-style-type: none"> • Sleep physiology and circadian rhythms • Sleep hygiene education (i.e., good sleep habits) not tailored to college students <ul style="list-style-type: none"> – Make bed and bedroom comfortable, ideal temperature for sleep, reduce noise and light – Exercise regularly but not 3 hours before bed and heavy meals before bedtime – Eat regular meals, avoid going to bed hungry or heavy meals before bedtime – Avoid excessive liquids in evening – Limit alcohol, caffeine, nicotine use – Establish a pre-bedtime sleep routine – Limit naps – Don't take worries to bed, deal with them in the morning
Module 2	<ul style="list-style-type: none"> • Sleep hygiene advice regarding sleep-disruptive behaviors and how to address them <ul style="list-style-type: none"> – Exercise – how exercise promotes sleep; exercise regularly for sleep but not 3 hours before bed – Eating habits – how eating affects sleep; eat regular meals, avoid going to bed hungry or heavy meals before bedtime; avoid excess liquids – Technology use – how it affects sleep; tips for limiting technology use and reducing light exposure – Limit alcohol, caffeine, nicotine use. Effects of these substances on sleep; risks of alcohol and insufficient sleep combined • Personalized feedback about alcohol use relative to peer norms • Personalized blood alcohol feedback • Moderate drinking recommendations • Controlled drinking strategies for moderating alcohol use • Effects of alcohol on the body 	<ul style="list-style-type: none"> • U.S. Department of Agriculture nutrition guidelines • Example meals that can be made in college dormitory living situations • Healthy eating is helpful for sleep
Module 3	<ul style="list-style-type: none"> • Effect of stress on sleep • Relaxation strategies <ul style="list-style-type: none"> – Deep, diaphragmatic breathing – Progressive muscle relaxation 	<ul style="list-style-type: none"> • Moderate drinking recommendations • Effects of alcohol on the body • Moderate drinking is better for sleep

	Call it a Night®	Healthy Behaviors
	<ul style="list-style-type: none"> • Cognitive strategies to target sleep-disruptive thoughts 	
Module 4	<ul style="list-style-type: none"> • Sleep hygiene advice regarding an ideal sleep-conducive environment in college <ul style="list-style-type: none"> – Make bed and bedroom comfortable, ideal temperature for sleep, reduce noise and light – Tips for how to create an ideal sleep environment if share a bedroom with a roommate 	<ul style="list-style-type: none"> • CDC guidelines for aerobic, strength, and flexibility exercise • Strategies for fitting exercise into college schedule and college dormitory living • Example exercises • Exercise is helpful for sleep

Table 3

End-of-treatment evaluation by condition (N = 38)

Characteristics	Call it a Night® (n = 19)	Healthy Behaviors (n = 19)	Test Statistics
Overall Satisfaction, M (SD) Range (1–10)	6.68 (1.95)	6.58 (2.52)	$F(3, 38) = 0.03, p = 0.87$
Understandability, M (SD) Range (1–5)	4.37 (0.76)	4.16 (1.02)	$F(3, 38) = 0.42, p = 0.52$
Enjoyment, M (SD) (Range 1–5)	3.26 (1.20)	2.84 (1.12)	$F(3, 38) = 1.16, p = 0.29$
Average Minutes Spent per Module, M (SD)	19.47 (12.68)	17.89 (9.02)	
Any Suggestions for Improvement, n (%)	7 (37)	9 (47)	Fisher's Exact
Make more tailored/personalized	6 (32)	5 (26)	Test = 1.00
Make more engaging/interactive	4 (21)	3 (16)	
Improve format of webpages	1 (5)	0	
Allow for quantifiable impact tracking	2 (11)	1 (5)	
Include links for supplemental information	1 (5)	3 (16)	

Table 4

Estimated means (SE) of alcohol consumption, alcohol-related consequences, and subjective sleep-related characteristics by condition and time (N = 42)

M (SE)	Call it a Night® (n = 21)				Healthy Behaviors (n = 21)			
	Intake	Week 5	3 Months	Effect Size	Intake	Week 5	3 Months	Effect Size
<i>Alcohol</i>								
Drinks Typical Week	17.95 (2.07)	16.34 (2.09)	11.15 (2.15)	d = -.68	18.16 (2.51)	13.63 (1.44)	8.56 (1.72)	d = -.80
Drinks Heaviest Week	27.50 (4.41)	25.24 (4.97)	20.40 (4.14)	d = -.34	24.96 (2.80)	18.01 (1.91)	11.10 (2.17)	d = -1.03
Consequences	15.83 (1.05)	11.02 (1.16)	8.75 (1.07)	d = -1.41	17.05 (.83)	9.48 (.59)	7.72 (.52)	d = -2.35
<i>Subjective Sleep Ratings</i>								
Sleep Quality	11.93 (.46)	10.85 (.44)	8.59 (.58)	d = -1.51	11.65 (.46)	10.13 (.43)	7.85 (.42)	d = -1.72
Sleep-Related Impairment	60.52 (1.67)	56.45 (1.31)	51.29 (1.83)	D = -1.15	65.41 (1.40)	55.02 (1.89)	50.14 (1.92)	d = -2.27

Note. Higher sleep quality scores on the PSQI are indicative of worse sleep quality. Effect sizes for the difference in drinking and sleep outcomes from intake to 3 months were calculated as the mean differences between the CIAN and HB conditions divided by the pooled standard deviation (Cohen, 1998). A Hedges' correction for sample size bias (Hedges, 1981).

Table 5
Estimated mean levels (SE) of quantitative sleep characteristics by condition and time (N = 42)

M (SE)	Call it a Night® (n = 21)				Healthy Behaviors (n = 21)			
	Intake	Week 4	Effect Size	Intake	Week 4	Effect Size	Intake	Effect Size
Sleep Duration (hours)	6:47 (.21)	6:70 (.15)	d = .23	6:58 (.13)	6:38 (.18)	d = -.32		
Bed time	1:37 (0:16)	1:42 (0:15)	d = .10	1:55 (0:13)	1:44 (0:16)	d = -.30		
Rise time	8:32 (0:12)	8:46 (0:13)	d = .42	8:57 (0:12)	8:46 (0:12)	d = -.31		
Sleep Efficiency	86.85 (.61)	86.13 (.75)	d = -.25	84.88 (1.37)	85.43 (1.13)	d = .08		

Effect sizes for the difference in drinking and sleep outcomes from intake to 3 months were calculated as the mean differences between the CIAN and HB conditions divided by the pooled standard deviation (Cohen, 1998). A Hedges' correction corrected for sample size bias (Hedges, 1981).