

Published in final edited form as:

Alcohol Clin Exp Res. 2011 May ; 35(5): 870–878. doi:10.1111/j.1530-0277.2010.01417.x.

SLEEP FOLLOWING ALCOHOL INTOXICATION IN HEALTHY, YOUNG ADULTS: EFFECTS OF SEX AND FAMILY HISTORY OF ALCOHOLISM

J. Todd Arnedt, PhD¹, Damaris J. Rohsenow, PhD², Alissa B. Almeida, MPH³, Sarah K. Hunt³, Manjusha Gokhale, MA⁴, Daniel J. Gottlieb, MD, MPH⁵, and Jonathan H. Howland, PhD, MPH, MPA³

¹ Sleep and Chronophysiology Lab, Department of Psychiatry, University of Michigan

² Center for Alcohol and Addiction Studies, Brown University

³ Dept of Community Health Sciences, Boston University School of Public Health

⁴ Data Coordinating Center, Boston University School of Public Health

⁵ VA Boston Healthcare System and Department of Medicine, Boston University School of Medicine

Abstract

Background—This study evaluated sex and family history of alcoholism as moderators of subjective ratings of sleepiness/sleep quality and polysomnography following alcohol intoxication in healthy, young adults.

Methods—Ninety-three healthy adults (mean age 24.4 ± 2.7 years, 59 women, 29 subjects with a positive family history of alcoholism (FH+)) were recruited. Following screening polysomnography, participants consumed alcohol (sex/weight adjusted dosing) to intoxication (peak breath alcohol concentration [BrAC] of 0.11 ± 0.01 g% for men and women) or matching placebo between 2030 and 2200 hours. Sleep was monitored with polysomnography between 2300 and 0700 hours. Participants completed the Stanford Sleepiness Scale and Karolinska Sleepiness Scale at bedtime and on awakening and a validated post-sleep questionnaire.

Results—Following alcohol, total sleep time, sleep efficiency, nighttime awakenings, and wake after sleep onset were more disrupted in women than men, with no differences by family history status. Alcohol reduced sleep onset latency, sleep efficiency, and REM sleep while increasing wakefulness and Slow Wave Sleep across the entire night compared to placebo. Alcohol also generally increased sleep consolidation in the first half of the night, but decreased it during the second half. Sleepiness ratings were higher following alcohol, particularly in women at bedtime. Morning sleep quality ratings were lower following alcohol than placebo.

Conclusions—Alcohol intoxication increases subjective sleepiness and disrupts sleep objectively more in healthy women than in men, with no differences evident by family history of alcoholism status. Evaluating moderators of alcohol effects on sleep may provide insight into the role of sleep in problem drinking.

Keywords

alcohol; sleep; polysomnography; sex; family history

INTRODUCTION

Alcohol effects on sleep have been studied extensively over the past 50–60 years, since early observations that pre-bedtime alcohol decreased body temperature and motility in the first half of the night, but increased them in the second half of the night (Kleitman, 1939). Studies conducted since then have consistently found that alcohol influences subjective ratings of sleepiness and sleep quality and objectively measured sleep parameters in healthy, young adults.

Following alcohol ingestion, subjective ratings of sleepiness increase compared to placebo (Rupp et al., 2007), but alcohol may have stimulant effects at low to moderate doses and during absorption, and sedative effects at higher doses and during alcohol elimination (Roehrs and Roth, 2001b) due to differential timing of effects on catecholamine production versus direct depressant effects (Filstead et al., 1976). Morning ratings may reflect reductions in estimated sleep onset latency after drinking (Roehrs et al., 1996), but next-day reports of increased fatigue and decreased mental alertness following alcohol are common (Finnigan et al., 1998). In some instances, sleep quality may be rated as improved relative to usual sleep, perhaps owing to facilitated sleep initiation (Rohsenow et al., 2006).

Nocturnal sleep has been assessed extensively with polysomnography (PSG) following low (.16 g/kg) and high (1.0 g/kg) alcohol doses, which produce peak breath alcohol concentrations (BrAC) of .006 to .10 g%, equivalent to roughly 1 to 6 standard drinks. Alcohol reduces sleep latency and has been shown to increase total sleep time at low but not moderate doses (Stone, 1980). It has minimal effects on nighttime sleep efficiency (total sleep time/time in bed*100) in healthy, young adults (Roehrs et al., 1991). Moderate alcohol doses also reliably alter Rapid Eye Movement (REM) and non-Rapid Eye Movement (NREM) sleep architecture. After absorption, alcohol is metabolized at a rate of roughly .01 – .02 g% per hour, thus its effects on sleep architecture differ as alcohol concentrations ascend and/or remain at peak during absorption (first half of the night) compared to the descending phase of alcohol metabolism (second half of the night). During the first half of the night, slow wave sleep percentage (SWS%) is increased (Feige et al., 2006; MacLean and Cairns, 1982; Williams et al., 1983) and REM sleep is suppressed, producing a prolonged REM latency (REM-L) and reduced REM% (Gillin et al., 2005; Kobayashi et al., 1998; Roehrs et al., 1991; Williams et al., 1983; Yules et al., 1966; Yules et al., 1967). The second half of the night is characterized by increased wakefulness, light Stage 1 sleep, and REM sleep (Feige et al., 2006; Knowles et al., 1968; MacLean and Cairns, 1982; Roehrs and Roth, 2001a; Roehrs and Roth, 2001b; Rundell et al., 1972; Williams et al., 1983), which is generally viewed as a rebound effect following the completion of alcohol metabolism.

Despite the general consensus in the literature regarding alcohol effects on sleep, several research questions remain unanswered. For example, nearly all studies have used small samples of men, yet the pharmacokinetics of alcohol differ between men and women. Women have less body water than men, so they reach a higher peak BrAC after an equivalent alcohol dose, even when doses are adjusted for body weight. BrAC rates also decline more rapidly in women after reaching peak as a result of a faster disappearance rate (rate of decrease in BrAC during the linear phase of elimination, expressed in grams per liter of blood per hour; Mumenthaler et al., 1999). The few sleep studies in women have been consistent with earlier studies in male samples (Van Reen et al., 2006; Williams et al., 1983), however, no study has had a sufficiently large sample of both men and women to evaluate sex differences adequately. Moreover, no study has compared effects of an equivalent dose of alcohol, adjusted for sex and weight, to target a narrow BrAC range, on sleep between men and women.

Several studies have found evidence of increased activity in the alpha band (8–13 Hz) during awake electroencephalography in subjects with a family history of alcoholism (Ehlers and Phillips, 2003; Ehlers et al., 2004), suggesting potentially higher levels of central nervous system arousal in these individuals. One recent study found that family-history positive subjects took longer to fall asleep on an objective sleepiness test than family-history negative individuals (Rupp et al., 2007). Only two studies have compared the nocturnal sleep of healthy boys and girls with and without a family history of alcoholism (Dahl et al., 2003; Tarokh and Carskadon, 2010). Both studies found no group differences in sleep continuity or architecture, but one study observed reduced delta and spindle power among family history positive subjects (Tarokh and Carskadon, 2010), while the other found that family-history positive boys had higher alpha activity than family-history negative boys (Dahl et al., 2003). No study, however, has assessed whether sleep differences exist following alcohol administration in family history positive and negative subjects.

Recently, we reported that intoxication with alcohol to 0.11 g% BrAC produced higher subjective sleepiness and lower sleep quality ratings and objectively disrupted select sleep architecture and continuity parameters more than placebo (Rohsenow et al., 2010). Sleep analyses in that report focused on whether a subset of sleep parameters moderated residual effects of alcohol on hangover and performance. In this report from the same study, we expand the sleep analyses to focus on sex and family history of alcoholism differences in subjective and objective sleep parameters following alcohol intoxication. We predicted that, compared to placebo, the high dose of alcohol would worsen sleep more in women than men but that nighttime sleep measures would be less disrupted in subjects with a family history of alcoholism. We also expected the high dose of alcohol to be more disruptive to sleep during the second half compared to the first half of the night.

MATERIALS AND METHODS

Participants

Young, healthy volunteers were recruited through advertisement in the greater Boston, Massachusetts area. Eligibility criteria included: 21 to 31 years of age; currently enrolled or recently graduated from college; no history of alcohol counseling or treatment and score < 5 on the Short Michigan Alcohol Screening Test (SMAST(Selzer et al., 1975)); ≥ 4 (for women) or ≥ 5 (for men) alcoholic beverages consumed on a single occasion at least once in the 30 days prior to the screen; no health problems or current medication use that would contraindicate alcohol consumption or affect the sleep/wake cycle; no sleep problems; no night shift work or travel across two or more time zones in the past month; and negative pregnancy test and not nursing, if female. Women were required to be using a reliable method of birth control to be eligible to participate but were not screened for or scheduled according to phase of the menstrual cycle (Brick et al., 1986; Niaura et al., 1987; Terner and deWit, 2006). Participants earned up to \$450 for study participation. The study procedures were approved by the Institutional Review Boards at the Boston Medical Center, Brown University, and University of Michigan.

Study Design

A double-blind, randomized, $2 \times 2 \times 2$ mixed design was used to evaluate alcohol content status (within subjects, alcohol vs. placebo) by beverage type (between subjects, high vs. low congener content) and order (alcohol on Day 1 vs. alcohol on Day 2). The high congener content beverage was bourbon, the low congener was vodka.

Procedures

Prior to testing, participants maintained an 8-hour time in bed schedule for minimum three days before each in-laboratory session, confirmed by a daily sleep-wake diary, continuous activity monitoring (Octagonal Basic Motionlogger, Ambulatory Monitoring, Inc., Ardsley, NY), and evening and morning call-in to a time-stamped answering machine. Participants abstained from napping for the duration of the study; alcohol, caffeine, and any drug use for 24 hours before each laboratory session; and food or beverage within 3 hours of testing. Adherence with these requirements was confirmed at the beginning of each testing session.

Following the at-home protocol, participants came to the General Clinical Research Center (GCRC) at the Boston Medical Center for two consecutive sessions (adaptation night, first experimental session) and then returned roughly one week later for another session (second experimental session). The adaptation session allowed for laboratory adaptation and screening for occult sleep disorders. Participants arrived at the GCRC at 1900 hours, where adherence with the at-home protocol was confirmed, the study protocol was reviewed, and participants practiced a neurocognitive battery of tests. Participants were prepared for overnight polysomnography and slept between 2300 and 0700 hours continuously monitored by a trained sleep technician and a medical technician. At 0700 hours, participants were awakened, had the electrodes removed, and completed the neurocognitive test battery between 0800 and 0930 hours (data not used in this report). Participants then left the laboratory for the day wearing the activity monitor.

For the experimental nights, participants were told they would receive alcohol on one night and placebo on the other and the chances of receiving alcohol the first night and vodka vs. bourbon were both 50-50. On each experimental night, some participants were consuming alcohol and others placebo. Participants reported to the GCRC at 1600 hours for the first experimental session, where they were screened for adherence with the study requirements, received a standardized meal with non-caffeinated beverage, were prepared for overnight polysomnography, and were randomized to beverage type (bourbon or vodka) and order (alcohol on first or second night). Beverages were consumed between 2030 and 2200 hours in groups of 2–4 under supervision. They were provided an 8-hour sleep opportunity between 2300 and 0700 hours. At 0700 hours, participants were awakened, completed subjective assessments, were served breakfast (no caffeine), and were breath tested. Between 0800 and 0930 hours, they completed subjective sleep measures and neurocognitive testing (reported in (Rohsenow et al., 2010)). One week later, participants returned for the second experimental testing session, identical to the first except for the beverage consumed (alcohol vs. placebo).

Beverage Administration Procedures—The alcoholic beverages were bourbon (101 proof Wild TurkeyR) or vodka (100 proof AbsolutR) mixed with chilled caffeine-free cola (CokeR) in a 1:4 ratio. The placebo for both beverages was an equivalent volume of chilled caffeine-free cola and de-carbonated tonic, with a few drops of vodka or bourbon floated on top. Alcohol was administered in doses of 1.2 g/kg for men and 1.1 g/kg for women (Friel et al., 1999) to achieve a peak BrAC of .10g%. Total beverage volume was determined by weight and gender (Friel et al., 1999) using dosing tables and divided into three equal portions.

Participants were told the number of cups they were to consume in an hour and monitored closely by study staff. Participants were breath tested 15 minutes after completing 2 of the 3 portions. Depending on their BrAC relative to the target, they then received an adjusted final quantity of beverage. Participants failing to reach 0.10 g% BrAC 15 minutes after completing the final portion consumed an additional portion of beverage within 5 minutes, estimated from the ratio of obtained to target BrAC. BrACs were then tested every 15

minutes until 2300 hours and again on awakening at 0700 hours. To maintain blinding, research staff that prepared beverages and conducted breath tests were different from the staff that interacted with participants and collected measures. After achieving the target BrAC, participants completed subjective measures, received snacks, and were escorted to their bedrooms for lights out at 2300 hours.

Polysomnographic (PSG) Recordings—Sleep was continuously recorded by PSG for the adaptation and two experimental nights between 2300 and 0700 hours and monitored by a trained sleep technician. Polysomnography included referentially recorded electroencephalogram (EEG) from left and right central and occipital electrode sites (C3/A2, C4/A1, O1/A2, and O2/A1), placed according to the International 10–20 System (Jasper, 1958), monopolar electrooculogram (EOG), bipolar mentalis/submentalis electromyogram (EMG), and bipolar electrocardiogram (ECG). Electrophysiological signals were recorded and digitized using Compumedics data acquisition software. EEG and EOG signals were filtered through digital amplifiers with high and low pass filter settings of .3 Hz and 30 Hz, respectively, with a 60 Hz notch filter. EMG was recorded with filters settings of 10 and 100 Hz. Data were digitized at 256 MHz.

Respiration and limb movements during sleep were assessed on adaptation and experimental nights. Thoracic and abdominal respiratory effort was monitored with inductive plethysmography, airflow was measured using a nasal pressure transducer, snoring was recorded with a snoring microphone, and blood oxygen saturation was measured by finger pulse oximetry. Limb movements were continuously monitored with bilateral electrodes placed over the anterior tibialis to assess for periodic limb movements in sleep. The adaptation night records were reviewed by one of the authors (JTA) and any volunteer with polysomnographic evidence of an ICSD-2-defined sleep disorder was excluded.

Dependent Measures

Individual Difference Measures—Recent drinking practices (past month) were established using a three-item alcohol use questionnaire: (1) “Considering all of your drinking times in the past 30 days, about how often did you have any beer, wine or liquor?” rated from 1 (once a day) to 7 (did not drink) with each point anchored; and (2) “In the past 30 days, on a typical day that you drank, about how much did you have to drink in one day?” with individual choices ranging from 1 to 7 drinks and “8 or more drinks”, and (3) “Almost everyone has times when he/she drinks and gets high or drunk or has a “buzz on”. How often has this happened to you in the past 30 days?” rated from 1 (once a day) to 8 (never) with each point anchored. Family history of alcoholism (FH+ or FH–) was ascertained with the interviewer-administered Family Tree Questionnaire (Mann et al., 1985), with a first- or second-degree biological relative with alcohol problems coded as FH +. The Morningness-Eveningness questionnaire was used to characterize self-reported circadian preference (Horne and Ostberg, 1976).

Subjective Sleepiness—The Stanford Sleepiness Scale (SSS; (Hoddes et al., 1973) and Karolinska Sleepiness Scale (KSS; (Gillberg et al., 1994) were administered before and after sleep to assess sleepiness. The SSS is a 7-item scale requiring participants to self-rate current sleepiness levels according to a scale anchored from 1 (feeling active and vital, wide awake) to 7 (almost in reverie, sleep onset soon, lost struggle to remain awake). The KSS is a 9-item scale anchored from 1 (extremely alert) to 9 (extremely sleepy – fighting sleep).

Sleep Quality Ratings—A post-sleep questionnaire (Roehrs et al., 1991) assessed estimated sleep latency, sleep duration, number and duration of nighttime awakenings, and four fully anchored ratings of sleep quality, sleep refreshment, level of alertness, and ability

to concentrate. The first two of these scales were anchored from “much better” (1) to “much worse” (5) compared to usual sleep at home (reverse scored in calculations), the latter two from “extremely poor” (1) to “excellent” (7). The mean of the four anchored scales is presented because they compose a reliable and valid scale (Roehrs et al., 1991; Rohsenow et al., 2006).

Polysomnography—Sleep records were visually scored off-line in 30-second epochs from C3/A2, EOG, and EMG using established criteria (Rechtschaffen and Kales, 1968) by a trained technician who was blind to alcohol vs. placebo administration. Sleep parameters were calculated for the entire night and separately by half of the night. Sleep continuity variables included sleep latency (SL; time from “lights out” to the first of 3 consecutive epochs of Stage 1 sleep or the first epoch of any other sleep stage), total sleep time (TST; the total minutes of REM and NREM sleep within the total sleep period [TSP; time between sleep onset and the last epoch of sleep]), sleep efficiency (SE; total sleep time/time between “lights out” and “lights on”), frequency of nighttime awakenings (FNA; sum of EEG-defined awakenings within the TSP), and wakefulness after sleep onset (WASO; total time awake from sleep onset to “lights on”). Sleep architecture variables included the minutes of wake and percentages of Stages 1, 2, Slow Wave Sleep (SWS; Stages 3 and 4), and REM in the TSP. Latency to SWS and REM (minutes from sleep onset to the first 30-second epoch of Stage 3 or REM sleep) were also computed.

Statistical Analyses

Data analyses were conducted using SPSS 17.0 (SPSS, Inc., Chicago, IL). Data are reported as mean \pm standard deviation unless otherwise indicated, with significance level set at 0.05. Variables that deviated significantly from normality were transformed for parametric analyses, but the original values are reported in tables and figures for ease of interpretation. In some cases, setting extreme values to 1 plus the next highest value corrected skewness due to outliers (Tabachnick and Fidell, 1996).

Initial analyses with t-tests and chi-squares indicated that no baseline demographic or drinking pattern differences existed by sex. Repeated measures analysis of variance (MANOVA procedure in SPSS) were conducted on the subjective measures and all-night PSG dependent variables first as 2×2 alcohol content (alcohol vs. placebo) by order (alcohol on first or second night) to rule out order effects and then as 2×2 alcohol content by sex to test the sex study hypotheses and a 2×2 alcohol content by family history of alcoholism to test the family history hypotheses. Analyses were not conducted as $2 \times 2 \times 2 \times 2$ because no other interactions were germane to the hypotheses.

To evaluate time of night study hypotheses for the PSG dependent variables (first vs. second half of the night), we conducted $2 \times 2 \times 2$ night half by alcohol content by sex and night half by alcohol content by family history of alcoholism split plot ANOVAs. Although not directly related to our primary study hypotheses, we did inspect main effects of sex. We previously reported no differences in subjective or objective sleep variables by beverage type (vodka vs. bourbon; Rohsenow et al., 2010), thus we did not consider beverage type in any of our analyses. Combined placebo data are presented, since no differences were found on any of the outcome variables between the vodka and bourbon placebos.

RESULTS

Participant Demographics

Of 122 participants enrolled in the study, 20 failed to complete the protocol, 5 failed to reach the minimum BrAC of 0.09 g%; 1 had incomplete PSG data due to equipment failure; and 3

were excluded for excessive periodic limb movements during sleep. The final sample consisted of 93 participants with complete sleep data on placebo and alcohol nights (mean age 24.3 ± 2.7 years, 59 women). Demographics, drinking variables, and morningness-eveningness scores of the participants by sex are shown in Table 1.

Breath Alcohol Concentrations (BrAC) and Manipulation Checks

Peak BrAC prior to bedtime was $0.11 \pm .01$ g% and did not differ by sex. Morning BrAC was 0.003 ± 0.008 g% (range 0.00 – 0.05 g%). In response to the question about beverage consumed, 85% of participants (77/91) accurately identified when they were administered placebo and 96% (88/92) correctly guessed when they received alcohol, with no differences between sex or family history of alcoholism.

Subjective Sleep and Sleepiness

Sleepiness Ratings—Evening and morning SSS and KSS ratings can be found in Table 2. For both scales, bedtime and morning sleepiness ratings were higher following alcohol than placebo (evening SSS $F(1,91) = 51.77$, $p < .001$; morning SSS $F(1,91) = 36.53$, $p < .001$; evening KSS $F(1,91) = 25.69$, $p < .001$; morning KSS $F(1,91) = 16.29$, $p < .001$). Bedtime sleepiness ratings on the SSS were additionally higher in women than men following alcohol ($F(1,91) = 51.8$, $p < .04$). Morning KSS ratings were lower in FH+ compared to FH- participants overall with no significant interaction by alcohol content (FH+: 5.4 ± 1.9 , FH-: 6.3 ± 1.7 , $F(1,90) = 4.32$, $p < .05$). No other significant interactions by order, sex, or family history of alcoholism were found.

Morning Ratings of Subjective Sleep Quality—Results from the post-sleep questionnaire are shown in Table 2. No significant main effects of alcohol content or interactions with sex or family history were found for estimates of sleep latency, total sleep time, nighttime awakenings, or wake after sleep onset. A significant alcohol content by order interaction was found for morning ratings of wake after sleep onset ($F(1,82) = 4.33$, $p < .05$), indicating that participants who received alcohol at the second session reported more wake after sleep onset than those who received alcohol first. The composite sleep quality index was reliable (Chronbach's $\alpha = 0.78$ following alcohol, 0.75 following placebo) and indicated that ratings were worse following alcohol ($F(1,86) = 43.77$, $p < .001$) with no significant sex or family history interactions. Ratings on this index also suggested better sleep quality ratings overall among FH+ participants ($F(1,85) = 4.96$, $p < .05$).

Polysomnography (PSG)

All Night—Sleep continuity and sleep architecture measures are shown by sex in Table 3. No significant interactions with order or family history of alcoholism were found for any of the PSG variables. In general, alcohol objectively disrupted sleep continuity more in women than in men. Specifically, the sleep of women following alcohol was characterized by a nearly 20-minute reduction in total sleep time and 15-minute increase in time spent awake during the night relative to the placebo night. Among women, the number of nighttime awakenings also increased and sleep efficiency decreased by nearly 4% across the night after consuming alcohol. By contrast, these sleep continuity variables changed little across the night for men from the placebo to the alcohol night. In terms of sleep architecture, alcohol reduced Slow Wave Sleep latency more in men than in women, although women had overall more Slow Wave Sleep ($27.2 \pm 6.2\%$ vs. $22.8 \pm 5.6\%$, $F(1,91) = 11.50$, $p < .001$) and Stage 2 sleep ($46.9 \pm 5.7\%$ vs. $50.6 \pm 6.0\%$, $F(1,91) = 8.47$, $p < .01$).

In addition to the sex by alcohol content differences, there were several main effects of alcohol for both the sleep continuity and sleep architecture PSG variables. Alcohol reduced sleep onset latency (8.8 ± 13.0 mins vs. 10.2 ± 13.6 mins, $p < .05$) and sleep efficiency (89.7

$\pm 8.5\%$ vs. 91.8 ± 6.3 , $p < .01$), and increased wakefulness during the night (36.9 ± 30.4 mins vs. 27.2 ± 20.9 mins, $p < .001$) compared to placebo. The primary effects of alcohol on sleep architecture were to increase SWS% ($26.5 \pm 7.7\%$ vs. $24.6 \pm 6.7\%$, $p < .05$) and decrease REM% ($20.3 \pm 6.2\%$ vs. $24.1 \pm 6.7\%$, $p < .001$), with a slight increase in the percentage of time spent in Stage 2 sleep ($49.2 \pm 7.7\%$ vs. $47.4 \pm 7.4\%$, $p < .05$). Participants entered SWS roughly 5 minutes earlier following alcohol (14.9 ± 10.9 vs. 19.3 ± 12.1 min, $p < .001$), while REM-L was lengthened by more than 30 minutes (132.7 ± 58.6 vs. 101.2 ± 42.0 mins, $p < .001$).

Half of the Night—A subset of the PSG variables compared by half of the night is shown in Table 4 by alcohol content. The effects of alcohol on sleep continuity and sleep architecture by half of the night did not differ between men and women or between FH+ and FH- participants. Alcohol and placebo effects on several sleep parameters did, however, differ by half of the night. Posthoc tests indicated that, during the first half of the night, alcohol increased total sleep time ($t(91) = 2.5$, $p < .05$) and sleep efficiency ($t(91) = 2.4$, $p < .05$) and decreased both the number and duration of awakenings (number: $t(91) = -2.6$, $p < .01$; duration: $t(91) = -3.0$, $p < .004$) compared to placebo. In the second half of the night, total sleep time ($t(91) = -2.8$, $p < .007$) and sleep efficiency ($t(91) = -3.0$, $p < .004$) were significantly reduced and the number ($t(91) = 2.2$, $p < .05$) and duration ($t(91) = 2.4$, $p < .02$) of awakenings were significantly increased by alcohol relative to placebo.

DISCUSSION

The primary focus of this study was to examine potential moderators of the effects of a high dose of alcohol on subjective and objective sleep measures in a large sample of healthy men and women. While previous studies of the effects of alcohol on sleep have consistently demonstrated changes in sleep continuity and sleep architecture, few have considered potentially important moderators of these effects. Our primary finding was that alcohol objectively disrupted sleep continuity more in women than men at equivalent BrACs, but that no sex differences were evident for alcohol effects on sleep architecture. On the other hand, participants with a family history of alcoholism did not have sleep differentially affected by alcohol.

To our knowledge, this study is the first to demonstrate sex differences in the effects of alcohol on sleep at equivalent BrACs. Consistent with our predictions, alcohol disrupted sleep more in women than men, although these effects were evident only across the entire night. Relative to placebo, alcohol reduced total sleep time by 19 minutes, decreased sleep efficiency by 4%, and increased wakefulness during the night by nearly 15 minutes among women. In comparison, sleep continuity following alcohol was equivalent to placebo in men. The greater sleep disruption in women may be related to sex differences in alcohol pharmacokinetics. Previous studies have shown that at equivalent peak BrACs, women show a more rapid decline of BrAC than men, which indicates a faster disappearance rate (Taylor et al., 1996). The absence of significant sex by time of the night interactions with alcohol content may have been due to the high dose of alcohol in this study. We do not believe that the observed differences are the result of drinking experience, since recent drinking practices, including the number of drinking days over the past 30 days and the number of drinks per drinking day, were equivalent between men and women. It is notable that the magnitude of the disruption from alcohol on PSG parameters in women was small, however, we enrolled only healthy participants who were self-described good sleepers with no evidence of personal substance abuse history or other psychopathology. It is possible that the effects would have been different in people with a history of insomnia or who were poor quality sleepers. Given the identified associations between poor sleep quality and the initiation of and relapse to alcohol use (Brower and Perron, 2009; Wong et al., 2004), it is

tempting to speculate that the greater alcohol-related sleep disruption could serve as a protective factor against problem drinking in young women. This issue merits further study.

In contrast to sleep continuity parameters, no sex differences were evident for alcohol effects on sleep architecture. Main effects of alcohol content on sleep architecture variables were evident, however. We found that alcohol increased Slow Wave Sleep and decreased REM sleep across the entire night. These entire night effects of alcohol on SWS and REM may have due to the high peak BrAC achieved in our study. Previous high dose studies (0.8 g/kg – 1.0 g/kg) failed to find entire night differences in REM and SWS percentages between placebo and alcohol, but these studies were based on very small samples of men and women (Feige et al., 2006; Prinz et al., 1980; Rundell et al., 1972; Yules et al., 1966). With an expected elimination rate of .01 – .02 g% per hour of sleep, many subjects in our study would have had sedative-promoting doses of alcohol for the majority of the night. This speculation is supported by the quantified morning BrAC in our subjects, which averaged .003 g%, with 15% of the sample having a positive BrAC on awakening. These findings underscore the influence of dose of alcohol on objective sleep parameters. Consistent with previous findings, there were clear time of night differences in the effects of alcohol on sleep: alcohol increased sleep consolidation in the first half of the night but decreased it during the second half of the night. The latter finding has been widely reported and is also consistent with the stimulant effects of low doses of alcohol (Filstead et al., 1976) occurring when BrACs are low toward the end of alcohol metabolism. In contrast to previous studies, we did not find time of night differences on sleep architecture variables.

Objective sex differences were not manifested in differential ratings of sleep quality the next morning between men and women. Also, while subjects rated their sleep quality as worse following alcohol than placebo, estimates of total sleep time, sleep latency, number of nighttime awakenings, and wakefulness during the night following alcohol were not different from placebo. This subjective/objective discrepancy, previously found in recovering alcoholic participants (Conroy et al., 2006) but not in healthy volunteers, may be reflective of the cognitive impairing effects of alcohol. Alternatively, the absence of subjective effects may have been due to the small objective changes in sleep continuity.

The high dose of alcohol in our study increased ratings of sleepiness at bedtime, particularly in women, on our validated measures of sleepiness. Subjects also rated themselves as more sleepy in the morning following alcohol despite an adequate enforced sleep opportunity period. This finding suggests that high dose of alcohol may confer increased risk for accidents involving sleepiness, such as motor vehicle crashes, not only in the evening, but also the next morning. Women may be at particular risk for experiencing the next-day impairing effects of alcohol that are due to sleepiness.

We found no differences in objective sleep measures by family history of alcoholism following alcohol, but FH+ subjects self-rated as less sleepy and self-reported better sleep quality overall than FH– subjects. These findings need to be interpreted cautiously given the very small number of FH+ males in particular. Preliminary studies have found some evidence of greater awake alpha activity and potential sex differences in the sleep of FH+ adolescents, but our study suggests that the response to an alcohol challenge in FH+ participants may not be different from FH– participants. This issue is of particular importance because FH+ subjects are more resistant to the acute intoxicating effects of alcohol than FH– subjects, when controlling for drinking history (Schuckit, 1994), and this factor has been identified as a risk factor for the development alcoholism (Schuckit, 1998). Thus, a question of scientific importance is whether FH+ subjects may exhibit similar resistance to the effects of alcohol on nocturnal sleep. We should note, however, that while we found no differences in sleep macroarchitecture, quantitative analyses of sleep

microarchitecture would provide a more sensitive and complete means of examining sleep-related differences between FH+ and FH− subjects.

The strengths of this study were the use of a rigorous double-blind placebo-controlled design and the inclusion of a large sample of well-characterized healthy men and women. The study did, however, have important limitations. Despite our best efforts at blinding, 82% and 92% of our sample correctly guessed when they received placebo and alcohol, respectively. This finding is not surprising, since alcohol administration studies using the balanced placebo design have shown that blinding is successful up to doses of .05 g% BrAC, but not at doses of .07 g% or higher (Rohsenow and Marlatt, 1981), yet few sleep and alcohol studies have reported the success of blinding manipulations. Beverage knowledge could therefore have biased responses to the sleepiness scale and morning questionnaire, but we think it less likely that it influenced the objective sleep measures. In two recent high dose studies using similar designs, we found no effect of alcohol compared to placebo on next-day objective performance measures, despite most subjects accurately identifying group assignment (Howland et al., 2010; Rohsenow et al., 2006). One would expect non-blinding to bias findings consistently in support of the alternative, rather than the null, hypothesis. Another limitation of our study is that we did not match our sample by sex or family history of alcoholism a priori, thus our comparisons based on these moderators may have failed to take into account important confounding variables, although the samples did not differ on the demographic and drinking history variables that we did collect. Finally, although our sample size was the largest of any study to date examining the effects of alcohol administration on sleep, it was comprised of young, healthy, well-educated, largely Caucasian participants, thus generalizability of our findings to other populations is limited.

In summary, we found that sleep disturbances were more evident in women than men at an equally high peak BrAC, but subjective ratings did not differ between sexes and only partially reflected the increased sleep disruption induced by alcohol. Sleep among those with a family history of alcoholism did not differ from family history negative subjects following alcohol consumption. Further exploration of the moderators of alcohol effects on sleep may help to characterize those who are most vulnerable to alcohol-related impairment and may further our understanding of the role that sleep plays in the development of problem drinking.

Acknowledgments

Support: R01 AA12087 (J Howland) and M01 RR00533

This research was supported by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) Grant #R01 AA12087 to the Boston University School of Public Health and the National Center for Research Resources, General Clinical Research Center grant M01 RR00533.

References

- Brick J, Nathan PE, Westrick E, Frankenstein W, Shapiro A. The effects of menstrual cycle on blood alcohol levels and behavior. *J Stud Alcohol*. 1986; 47:472–477. [PubMed: 3795962]
- Brower KJ, Perron BE. Sleep disturbance as a universal risk factor for relapse in addictions to psychoactive substances. *Med Hypotheses*. 2010; 74:928–933. [PubMed: 19910125]
- Conroy DA, Arnedt JT, Brower KJ, Strobbe S, Consens F, Hoffmann R, Armitage R. Perception of sleep in recovering alcohol-dependent patients with insomnia: Relationship with future drinking. *Alcohol Clin Exp Res*. 2006; 30:1992–1999. [PubMed: 17117964]
- Dahl RE, Williamson DE, Bertocci MA, Stolz MV, Ryan ND, Ehlers CL. Spectral analyses of sleep EEG in depressed offspring of fathers with or without a positive history of alcohol abuse or dependence: a pilot study. *Alcohol*. 2003; 30:193–200. [PubMed: 13679113]

- Ehlers CL, Phillips E. EEG low-voltage alpha and alpha power in African American young adults: Relation to family history of alcoholism. *Alcohol Clin Exp Res*. 2003; 27:765–772. [PubMed: 12766620]
- Ehlers CL, Phillips E, Wall TL, Wilhelmsen K, Schukit MA. EEG alpha and level of response to alcohol in Hispanics and Non-Hispanic-American young adults with a family history of alcoholism. *J Stud Alcohol*. 2004; 65:301–308. [PubMed: 15222586]
- Feige B, Gann H, Brueck R, Hornyak M, Litsch S, Hohagen F, Riemann D. Effects of alcohol on polysomnographically recorded sleep in healthy subjects. *Alcohol Clin Exp Res*. 2006; 30:1527–1537. [PubMed: 16930215]
- Filstead, WJ.; Rossi, JJ.; Keller, M. Alcohol and alcohol problems: New thinking and new directions. Cambridge, MA: Balinger Publishing; 1976.
- Finnigan F, Hammersley R, Cooper T. An examination of next-day hangover effects after a 100 mg/100 ml dose of alcohol in heavy social drinkers. *Addiction*. 1998; 93:1829–1838. [PubMed: 9926571]
- Friel PN, Logan BK, O'Malley D, Baer JS. Development of dosing guidelines for reaching selected target breath alcohol concentrations. *J Stud Alcohol*. 1999; 60:555–565. [PubMed: 10463813]
- Gillberg M, Kecklund G, Akerstedt T. Relations between performance and subjective ratings of sleepiness during a night awake. *Sleep*. 1994; 17:236–241. [PubMed: 7939123]
- Gillin, JC.; Drummond, SPA.; Clark, CP.; Moore, P. Medication and substance abuse. In: Kryger, MH.; Roth, T.; Dement, WC., editors. *Principles and Practice of Sleep Medicine*. 4. Philadelphia: Elsevier Saunders; 2005.
- Hoddes E, Dement W, Zarcone V. Quantification of sleepiness: A new approach. *Psychophysiology*. 1973; 10:431–436. [PubMed: 4719486]
- Horne JA, Ostberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol*. 1976; 4:97–110. [PubMed: 1027738]
- Howland J, Rohsenow DJ, Greece JA, Littlefield CA, Almeida A, Heeren T, Winter M, Bliss CA, Hunt S, Hermos J. The effects of binge drinking on college students' next-day academic test-taking performance and mood state. *Addiction*. 2010; 105:655–665. [PubMed: 20403018]
- Jasper HH. The ten-twenty electrode system of the International Federation. *Electroencephalogr Clin Neurophysiol*. 1958; 10:371–375.
- Kleitman, N. Sleep and wakefulness. Chicago, IL: The University of Chicago Press; 1939.
- Knowles JB, Laverty SG, Kuechler HA. Effects of alcohol on REM sleep. *Q J Stud Alcohol*. 1968; 29:342–349. [PubMed: 5662828]
- Kobayashi T, Misaki K, Nakagawa H, Okuda K, Ota T, Kanda I, Isaki K, Kosino Y, Fukuda H. Alcohol effect on sleep electroencephalography by Fast Fourier Transformation. *Psychiatry Clin Neurosci*. 1998; 52:154–155. [PubMed: 9628123]
- Maclean AW, Cairns J. Dose-response effects of ethanol on the sleep of young men. *J Stud Alcohol*. 1982; 43:434–444. [PubMed: 7144178]
- Mann RE, Sobell LC, Sobell MB, Pavan D. Reliability of a family tree questionnaire for assessing family history of alcohol problems. *Drug Alcohol Depend*. 1985; 15:61–67. [PubMed: 4017879]
- Mumenthaler MS, Taylor JL, O'Hara R, Yesavage J. Gender differences in moderate drinking effects. *Alcohol Res Health*. 1999; 23:55–64. [PubMed: 10890798]
- Niaura RS, Nathan PE, Frankenstein W, Shapiro AP, Brick J. Gender differences in acute psychomotor, cognitive, and pharmacokinetic response to alcohol. *Addict Behav*. 1987; 12:345–356. [PubMed: 3687517]
- Prinz PN, Roehrs TA, Vitaliano PP, Linnoila M, Weitzman ED. Effect of alcohol on sleep and nighttime plasma growth hormone and cortisol concentrations. *J Clin Endocrinol Metab*. 1980; 51:759–764. [PubMed: 7419664]
- Rechtschaffen, A.; Kales, A. A Manual of Standardized Terminology, Techniques, and Scoring System for Sleep Stages of Human Subjects. Los Angeles: UCLA Brain Information Service/Brain Research Institute; 1968.
- Roehrs T, Petrucelli N, Roth T. Sleep restriction, ethanol effects and time of day. *Hum Psychopharmacol*. 1996; 11:199–204.

- Roehrs T, Roth T. Sleep, sleepiness, and alcohol use. *Alcohol Res Health*. 2001a; 25:01–9.
- Roehrs T, Roth T. Sleep, sleepiness, sleep disorders and alcohol use and abuse. *Sleep Med Rev*. 2001b; 5:287–297. [PubMed: 12530993]
- Roehrs T, Yoon J, Roth T. Nocturnal and next-day effects of ethanol and basal level of sleepiness. *Hum Psychopharmacol*. 1991; 6:307–312.
- Rohsenow DJ, Howland J, Arnedt JT, Almeida AB, Greece J, Minsky S, Kempler CS, Sales S. Intoxication with bourbon versus vodka: Effects on hangover, sleep, and next-day neurocognitive performance in young adults. *Alcohol Clin Exp Res*. 2010; 34:509–518. [PubMed: 20028364]
- Rohsenow DJ, Howland J, Minsky SJ, Arnedt JT. Effects of heavy drinking by maritime academy cadets on hangover, perceived sleep, and next-day ship power plant operation. *J Stud Alcohol*. 2006; 67:406–415. [PubMed: 16608150]
- Rohsenow DJ, Marlatt AG. The balanced placebo design: Methodological considerations. *Addict Behav*. 1981; 6:107–122. [PubMed: 7023202]
- Rundell OH, Lester BK, Griffiths WJ, Williams HL. Alcohol and sleep in young adults. *Psychopharmacologia*. 1972; 26:201–18. [PubMed: 4342143]
- Rupp TL, Acebo C, Van Reen E, Carskadon MA. Effects of a moderate evening alcohol dose. I: Sleepiness. *Alcohol Clin Exp Res*. 2007; 31:1358–1364. [PubMed: 17550363]
- Schuckit MA. A clinical model of genetic influences in alcohol dependence. *J Stud Alcohol*. 1994; 55:5–17. [PubMed: 8189726]
- Schuckit MA. Biological, psychological and environmental predictors of the alcoholism risk: A longitudinal study. *J Stud Alcohol*. 1998; 59:485–494. [PubMed: 9718100]
- Selzer ML, Vinokur A, Van Rooijen L. A self-administered Short Michigan Alcoholism Screening Test (SMAST). *J Stud Alcohol*. 1975; 36:117–126. [PubMed: 238068]
- Stone BM. Sleep and low doses of alcohol. *Electroencephalogr Clin Neurophysiol*. 1980; 48:706–709. [PubMed: 6155259]
- Tabachnick, BG.; Fidell, LS. Using multivariate statistics. 3. New York: Harper Collins; 1996.
- Tarokh L, Carskadon MA. Sleep electroencephalogram in children with a parental history of alcohol abuse/dependence. *J Sleep Res*. 2010; 19:165–174. [PubMed: 19735444]
- Taylor JL, Dolhert N, Friedman L, Mumenthaler M, Yesavage JA. Alcohol elimination and simulator performance of male and female aviators: A preliminary report. *Aviat Space Environ Med*. 1996; 67:407–413. [PubMed: 8725465]
- Terner JM, deWit J. Menstrual cycle phase and responses to drugs of abuse in humans. *Drug Alcohol Depend*. 2006; 84:1–13. [PubMed: 16413143]
- Van Reen E, Jenni OG, Carskadon MA. Effects of alcohol on sleep and the sleep electroencephalogram in healthy young women. *Alcohol Clin Exp Res*. 2006; 30:974–981. [PubMed: 16737455]
- Williams DL, Maclean AW, Cairns J. Dose-response effects of ethanol on the sleep of young women. *J Stud Alcohol*. 1983; 44:515–523. [PubMed: 6645531]
- Wong MM, Brower KJ, Fitzgerald HE, Zucker RA. Sleep problems in early childhood and early onset of alcohol and other drug use in adolescence. *Alcohol Clin Exp Res*. 2004; 28:578–587. [PubMed: 15100609]
- Yules RB, Freedman DX, Chandler KA. The effect of ethyl alcohol on man's electroencephalographic sleep cycle. *Electroencephalogr Clin Neurophysiol*. 1966; 20:09–11.
- Yules RB, Lippman ME, Freedman DX. Alcohol administration prior to sleep. The effect on EEG sleep stages. *Arch Gen Psychiatry*. 1967; 16:94–7. [PubMed: 6015940]

Table 1

Participant demographics and peak breath alcohol concentrations (mean (sd) or n (%)) by sex.

	Men (n=34)	Women (n=59)	Total (n=93)
Age (years)	24.4 (2.2)	24.3 (3.0)	24.4 (2.7)
Race			
White	26 (76.5)	50 (84.7)	76 (81.7)
Black	3 (8.8)	0 (0)	3 (3.2)
Asian	2 (5.9)	2 (3.4)	4 (4.3)
Other	3 (8.8)	7 (11.9)	10 (10.8)
Body Mass Index	23.9 (3.2)	24.4 (4.2)	24.2 (3.8)
Currently Enrolled in College	9 (26.5)	18 (30.5)	27 (29.0)
Drinking practices in past 30 days			
Consumed alcohol \geq once per week	31 (91.1)	54 (91.5)	85 (91.4)
High or drunk \geq once per week	17 (50.0)	27 (45.8)	44 (47.4)
Number drinks per drinking day	3.5 (1.7)	3.2 (1.3)	3.3 (1.4)
Positive family history of drinking problems	6 (17.6)	21 (35.6)	27 (29.0)
Morningness-Eveningness Questionnaire Total Score [§]	48.3 (8.7)	49.5 (8.3)	49.0 (8.4)
Epworth Sleepiness Scale [¥]	6.0 (3.9)	6.7 (3.1)	6.4 (3.4)
Peak breath alcohol concentration (g%)	0.11 (0.01)	0.11 (0.01)	0.11 (0.01)

[§] 16–30=Definitely Evening Type; 31–41=Moderately Evening Type; 42–58=Neither Type; 59–69=Moderately Morning Type; 70–86=Definitely Morning Type

[¥] Range 0 to 24, with higher scores indicative of greater daytime sleepiness

Table 2

Subjective sleepiness and post-sleep questionnaire (mean (sd)) between alcohol and placebo by sex.

	Men (n=34)		Women (n=59)	
	Placebo	Alcohol	Placebo	Alcohol
SSS[†]				
Evening ^{***}	3.8 (1.5)	4.7 (1.4)	3.7 (1.4)	5.3 (1.0)
Morning ^{***}	2.7 (1.1)	3.5 (1.2)	2.5 (1.0)	3.5 (1.2)
KSS[‡]				
Evening ^{***}	5.7 (1.9)	6.6 (2.0)	5.4 (2.0)	7.1 (1.5)
Morning ^{***}	5.4 (2.0)	6.4 (1.5)	5.2 (1.9)	5.8 (1.9)
Post-Sleep Questionnaire				
Sleep latency (min)	25.8 (20.8)	19.8 (24.6)	20.2 (20.0)	18.0 (21.4)
Total sleep time (min)	420.0 (67.6)	422.0 (50.0)	428.8 (63.3)	420.6 (58.7)
Nighttime awakenings (#)	2.0 (1.2)	2.3 (1.2)	2.4 (1.6)	2.5 (1.5)
Wake after sleep onset (min) Sleep Quality Composite	31.6 (74.0)	26.8 (33.4)	19.0 (27.7)	30.2 (39.3)
Index (1–6) [§] ^{***}	3.4 (0.5)	2.9 (0.6)	3.6 (0.6)	3.0 (0.7)

[†]SSS=Stanford Sleepiness Scale (1=Feeling active and vital; wide awake; 2=Functioning at a high level, but not at peak; able to concentrate; 3=Relaxed; awake; not at full alertness; responsive; 4=A little foggy; not at peak; let down; 5=Fogginess; beginning to lose interest in remaining awake; slowed down; 6=Sleepiness; prefer to be lying down; fighting sleep; woozy; 7=Almost in reverie; sleep onset soon; lost struggle to remain awake)

[‡]KSS=Karolinska Sleepiness Scale (1=Extremely alert; 3=Alert; 5=Neither alert nor sleepy; 7=Sleepy - but no difficulty remaining awake; 9=Extremely sleepy - fighting sleep)

[§]Range 1 to 6, with higher scores indicative of better perceived sleep quality

^{***}p < .001 based on repeated measures ANOVA for alcohol vs. placebo

Table 3

All night polysomnography (mean (sd)) between alcohol and placebo by sex.

	Men (n=34)		Women (n=59)		Alcohol vs. Pbo F (1,91)	Alcohol content* Sex F (1,91)
	Placebo	Alcohol	Placebo	Alcohol		
Sleep Continuity						
Sleep latency (min)	12.9 (19.1)	9.0 (13.1)	8.6 (9.0)	8.7 (13.0)	4.41 *	1.86
Total sleep time (min)	427.8 (39.3)	429.2 (27.2)	441.8 (23.9)	423.0 (49.4)	0.12	4.65 *
Sleep Efficiency (%)	90.1 (8.0)	90.6 (5.8)	92.8 (4.9)	89.2 (9.8)	7.38 **	6.59 **
Awakenings (#)	14.4 (6.3)	13.2 (6.4)	11.8 (6.2)	13.1 (5.4)	0.00	4.77 *
Wake after sleep onset (min)	31.7 (24.0)	32.9 (21.0)	24.7 (18.7)	39.2 (34.7)	11.32 ***	6.53 **
Sleep Architecture‡						
Stage 1 (%)	4.5 (2.8)	4.1 (2.9)	3.5 (2.7)	4.0 (2.7)	0.02	2.68
Stage 2 (%)	49.3 (8.3)	51.8 (6.9)	46.2 (6.6)	47.6 (7.8)	3.91 *	0.31
Slow Wave Sleep (%)	22.0(6.7)	23.6(6.0)	26.2(6.2)	28.2(8.1)	5.89 *	0.05
Stage REM (%)	24.2(7.1)	20.5(5.5)	24.1(6.6)	20.2(6.6)	29.54 ***	0.03
REM latency (min)	99.6 (40.2)	134.4 (54.4)	102.1 (43.2)	131.7 (61.3)	20.69 ***	0.13
SWS latency (min)	23.3(15.2)	15.2(11.0)	17.0(9.2)	14.7(10.9)	25.50 ***	5.19 *

* p < .05;

** p < .01;

*** p < .001

[‡] Sleep architecture parameters calculated within total sleep period.

Table 4Polysomnography (mean (sd)) following alcohol and placebo by half of the night.[§]

	First Half (n=92)		Second Half (n=92)		Alcohol content*Half F (1,90)	Alcohol content*Half* Sex F (1,90)
	Placebo	Alcohol	Placebo	Alcohol		
Sleep Continuity						
Total sleep time (min)	215.0(18.8)	220.23(17.2)	218.7(17.2)	208.7(34.9)	18.41***	0.02
Sleep Efficiency (%)	90.6 (7.7)	92.9 (6.6)	92.0 (6.7)	87.8 (14.5)	18.18***	0.16
Awakenings (#)	7.0 (3.9)	5.8 (3.3)	5.8 (3.5)	6.8 (4.0)	13.83***	0.12
Sleep Architecture						
Wake time (min)	14.8 (15.4)	9.7 (10.6)	12.1 (12.2)	17.5 (18.5)	17.52***	1.02
Stage 1 (%)	4.3 (4.0)	3.7 (4.5)	3.6 (2.7)	5.2 (9.3)	8.44**	0.54
Stage 2 (%)	47.3 (11.7)	46.6 (10.1)	48.9 (11.8)	50.1 (13.0)	1.34	0.48
Slow Wave Sleep (%)	25.3 (16.7)	26.4 (18.5)	27.3 (18.5)	22.6 (17.6)	15.27***	1.96
Stage REM (%)	23.0 (11.6)	23.6 (14.6)	20.1 (12.9)	22.0 (11.4)	0.93	0.46

**
p < .01;***
p < .001[§]Second half of the night PSG calculations unavailable for one participant.