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Night-to-Night Sleep Variability in Older Adults with and Without Chronic Insomnia

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Abstract

Objectives—1) To quantify night-to-night variability in sleep behaviors and sleep measures among older chronic insomnia (CI) subjects and non-insomnia (NI) controls; 2) to investigate systematic temporal patterns of sleep behaviors and sleep measures across nights; and 3) to examine clinical correlates of sleep variability.

Methods—Sixty-one older adults with CI (71.4 years old, 67%F) and 31 older adults with NI (70.7 years old, 65%F) completed questionnaires and kept sleep diaries and wore wrist actigraphs for two weeks. Mixed models were used to estimate within-subject mean and standard deviation values; these were then compared across groups. Mixed models were also used to determine associations across nights of sleep measures.

Results—CI and NI differed on mean values for clinical ratings and sleep diary measures, but not for actigraphy measures. CI also showed significantly greater variability than NI on most sleep diary measures and on actigraphically-measured wakefulness after sleep onset (WASO) and sleep efficiency. Among CI, neither diary nor actigraphy measures from one night correlated with values from the previous night. Diary WASO and sleep time and actigraphy sleep latency and sleep time, however, positively correlated with values from the previous two nights. Variability measures were not correlated with other global clinical measures among CI.

Conclusions—Compared to NI, older adults with CI report worse sleep and greater night-to-night variability, which was confirmed with actigraphy. There was little evidence for positive or negative correlation of sleep measures across nights. Variability of sleep may be an important target for insomnia treatments.

Keywords

insomnia; sleep diary; sleep; behavioral treatment; variability

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1. INTRODUCTION

Psychological and neurobehavioral models suggest that voluntary sleep-wake behaviors, such as excessive time in bed and irregular sleep-wake timing, may contribute to the development of insomnia (1–4). For example, an individual who experiences a night of poor sleep may try to “catch up” by staying in bed longer the following morning or by going to bed earlier the following night. Such compensatory behaviors are thought to be maladaptive: increasing time in bed can lead to even worse sleep on subsequent nights, as time in bed further outstrips the individual’s actual ability to sleep. Lying awake in bed also contributes to conditioned arousal. Homeostatic mechanisms may eventually lead to improved “recovery” sleep after several nights of insomnia (5;6), but could further contribute to variability of sleep behaviors, sleep quantity, and sleep quality. Qualitative research supports the notion that unpredictability or variability of sleep is a source of frustration and distress to chronic insomnia sufferers (7).

Conversely, psychological and behavioral treatments for insomnia rely on voluntary changes in sleep-wake behavior and timing to reduce symptoms. Reduction of time in bed and establishing regular sleep-wake times are common features of interventions including sleep hygiene instruction, stimulus control therapy, sleep restriction, and cognitive behavioral therapy (8). Regularity and variability of sleep behaviors have also been recommended as a measure of treatment adherence in behavioral insomnia treatments (9). Therefore, night-to-night variability of sleep patterns in insomnia is important from the perspectives of etiology, treatment, and treatment adherence. Although this paper focuses on short-term, night-to-night variability of insomnia symptoms, insomnia patients may also show symptom variability over longer time intervals. For instance, patients with sleep-onset or sleep maintenance symptoms may show different symptom types when assessed 6 months later (10).

The collection of prospective longitudinal data on sleep-wake patterns with sleep diaries and actigraphy is recommended as a standard research procedure for insomnia (11). Sleep diaries are often used to establish within-subject or within-group mean values as primary outcomes. Evaluation of night-to-night variability has also been recommended as a potentially useful research tool (9), but there are no current standards for how this variability is best characterized.

Previous studies using sleep diaries and polysomnography do indeed suggest that individuals with insomnia have more short-term variability of sleep times and sleep measures than non-insomnia controls (12–14). This conclusion comes mainly from inspection of group variance measures such as standard deviation and standard error of the mean. Longitudinal data from individual subjects also provide a rich source for examining variability (15;16), but methods for quantifying this type of variability have not been well-developed. We are not aware of published studies examining variability of actigraphy measures in insomnia and control subjects.

Few studies have systematically addressed methods for quantifying night-to-night variability in insomnia. Wohlgemuth and colleagues addressed the question of how many nights are needed to calculate stable estimates of sleep parameters in older insomnia and control subjects (17). For both groups, random variation across nights and subjects was greater than systematic variability related to individual subjects or study nights. Insomnia subjects showed lower individual stability for most sleep diary parameters than controls, and they generally required a greater number of nights to provide a stable estimate of these parameters. These findings suggest greater night-to-night variability in the insomnia group. This study focused on estimating stability, rather than variability. More recently, Vallières and colleagues addressed the question of night-to-night variability in the sleep patterns of chronic insomnia patients using cluster analysis (6). They identified three clusters of patients based on the predictability of poor

sleep; one of these clusters had highly variable patterns. This study did not include non-insomnia control subjects.

The present study extends these previous observations in several ways. We analyzed night-to-night variability of both insomnia patients and non-insomnia controls, we used both sleep diary and actigraphy outcomes, and we examined clinical correlates of this variability. The specific goals of this study were: 1) to quantify night-to-night variability in voluntary sleep behaviors (bed time, rise time, time in bed) and in sleep-wake measures (e.g., sleep latency, total sleep time, wake after sleep onset, sleep efficiency, sleep quality) in a group of older insomnia subjects and non-insomnia controls; 2) to determine whether insomnia or non-insomnia subjects have any systematic temporal pattern of sleep behaviors or sleep patterns across nights; and 3) to determine whether night-to-night variability of sleep behaviors and sleep measures are related to other critical clinical measures.

2. METHODS

These data were collected as part of an ongoing study of older adults with chronic insomnia (CI) and their response to behavioral treatment (18). Part of this study also involves comparisons to older adults with no insomnia (NI). The study is part of a broader program project examining behavioral intervention strategies for sleep problems of older adults (AG 20677, T. Monk, Principal Investigator). Participants underwent telephone screening, an in-person diagnostic evaluation, and baseline data collection including questionnaires and two weeks of sleep diary and actigraphy. Insomnia subjects also had in-home polysomnography. The current analyses focus only on the pre-treatment baseline period, for which data were available in both CI and NI. This study was approved by the University of Pittsburgh Biomedical Institutional Review Board. All participants provided written informed consent and were compensated monetarily for their participation.

2.1 Participants

Participants included the first 61 older adults with insomnia and 31 control subjects out of a targeted enrollment of 80 and 40 for this study. All participants were at least 60 years of age and were recruited from a participating primary care practice ($n = 17$) or from the community via advertisements ($n = 59$). Participants with insomnia were required to meet the general criteria for insomnia disorder in the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV) (19) and the International Classification of Sleep Disorders, 2nd Edition (20). Specifically, these criteria include a sleep complaint lasting for at least one month, adequate opportunity and circumstances for sleep, and evidence of significant distress or daytime impairment. In order to enhance the generalizability and clinical relevance of our study, we did not apply the exclusion criteria of DSM-IV for medical or psychiatric disorders. Therefore, many of our subjects would be considered to have “comorbid insomnia.” Exclusion criteria included the presence of dementia (identified by history or a score <25 on the Folstein Mini Mental Status Exam [21]) or delirium; previously undiagnosed and untreated depressive, anxiety, psychotic, or substance use disorders (those with stably-treated depressive and anxiety disorders were not excluded); untreated obstructive sleep apnea syndrome, restless legs syndrome or other sleep disorders (those with stably-treated sleep disorders were not excluded); hospitalization within the past two weeks; ongoing chemotherapy or other cancer treatment; and terminal illness with life expectancy less than 6 months. Control subjects were recruited from the same sources and met the same inclusion and exclusion criteria, except for the presence of insomnia.

Potential subjects were evaluated with a telephone screening interview, followed by an in-person interview conducted by the project coordinator and supervised by study investigators. Initial assessment and diagnosis were assisted by the use of a screening sleep diary, locally-

developed sleep, medical history, and medication surveys, and sleep and psychiatric symptom questionnaires. In order to promote generalizability across a range of severity, no specific quantitative sleep criteria were used to qualify insomnia or control subjects.

2.2 Measures

The major outcome measures for this study were derived from sleep diary and actigraphy data. In particular, we examined within-subject variability over a two-week measurement period, estimated from each subject's standard deviation on diary and actigraphy measures. Other variables were used to characterize the sample, as described below.

The *Pittsburgh Sleep Diary* (22) is a prospective self-report measure of daytime activities, sleep behaviors, and sleep parameters. The morning portion specifically inquires about bed time and rise time (here reported as minutes from midnight and 0700, respectively), sleep latency, wakefulness after sleep onset (WASO), and sleep quality upon arising (0–100 on a visual analog scale). The recorded sleep parameters are used to calculate time in bed, total sleep time, and sleep efficiency (total sleep time/time in bed X 100). We have demonstrated that the PghSD is sensitive to differences between sleep disorder patients and controls (22) and to behavioral treatment effects (18). The sleep diary was collected for two weeks at baseline in both insomnia and control subjects and throughout the four-week intervention period in insomnia subjects.

Wrist actigraphy was measured with the Minimitter Actiwatch-64[®] device (Respironics, Inc., Murrysville, PA), which was worn concurrently with the collection of sleep diary data for two weeks. Data were collected in one-minute bins and analyzed with the Actiware Version 5.04 software program. Sleep diary data for bed time and rise time were entered for calculation of sleep-wake variables. Each actigraphy record was visually inspected to determine whether the participant's stated bed times and rise times were plausibly related to the observed activity patterns. In cases where an obvious discrepancy existed, the bed times and/or rise times for sleep diary and actigraphy were edited based on participants' reports and the observed activity patterns. A total of 62 out of 1622 (3.8%) daily records were edited in this way. Outcome variables for these analyses included sleep latency, wake after sleep onset (WASO), total sleep time and sleep efficiency. We used definitions provided by the Actiware software for these variables, which rely on values for bed time and rise time from the sleep diary.

Participant *demographic information* included age, gender, race, highest educational level, and subjective socioeconomic status (SES) using the SES Ladder (23). Measures used to characterize sleep-wake and circadian characteristics included the *Pittsburgh Sleep Quality Index* (PSQI) (24) for habitual subjective sleep quality; the *Epworth Sleepiness Scale* (ESS) (25) for daytime sleepiness; the *Composite Scale of Morningness* (26) to indicate the degree to which an individual is "morning oriented" in his or her preferred times of doing things; and the *Social Rhythm Metric* 5-item version (27;28), which quantifies the regularity of a person's daily habits and is collected in conjunction with the PghSD.

Participants' psychological status was characterized using the 17-item *Hamilton Rating Scale for Depression* (HAM-D) (29) for depressive symptoms and the *Hamilton Anxiety Rating Scale* (30) for anxiety symptoms. The *Mini Mental State Exam* (21) was used to screen potential participants for dementia.

Medical status was evaluated with the *Comorbidity Questionnaire* developed at the Center for Research on Chronic Disorders at the University of Pittsburgh's School of Nursing. It is adapted from the Charlson Comorbidity Index (31;32) but evaluates a wider range of conditions which we grouped into 17 categories. We also categorized participants' *current medications* into 15 categories. Table 1 reports the mean number of medical conditions and medications taken by

participants within each group. Finally, we characterized participants' health-related quality of life with the *Medical Outcomes Survey Short Form-36* (33;34). For this study, we simply reported the single item on self-reported general health.

2.3 Statistical methods

Insomnia and control subjects' clinical characteristics were compared using chi-square tests for categorical variables, t-tests for normally distributed variables, and Wilcoxon tests for non-normally distributed data. For Aim 1 (variability in insomnia vs. control subjects), we used mixed models to estimate each subject's mean value and night-to-night variability, represented by within-subject standard deviation, for each sleep diary and actigraphy measure. Likelihood ratio tests were then used to compare the within-subject mean and standard deviation across CI and NI groups. The advantage of mixed models is that they use all available data to estimate individual subject variability, and are less sensitive to missing values than other methods, such as simply calculating each subject's mean and standard deviation. For Aim 2 (temporal pattern), mixed models were used to determine if sleep measures on one night were related to the values for that measure one, two, or three nights previously, as indicated by the significance values for coefficients Y_{t-1} , Y_{t-2} , and Y_{t-3} . The previous nights' values were entered as covariates, and nonsignificant terms were dropped from the model. Analyses were conducted separately for CI and NI. For Aim 3, we used Pearson's correlations to examine the relationship between variability estimates and other clinical measures. Specifically, independent variables were individual subject's standard deviations from sleep diary or actigraphy, and the dependent measures were values for the PSQI, ESS, and HAM-D.

3. RESULTS

3.1 Demographic and clinical data (Table 1)

The groups were well-matched for age, sex, and self-rated socioeconomic status, but the control group was more highly educated. CI and NI showed the expected differences in rating scales evaluating sleep and psychological symptoms. Of note, the groups did not differ on the Social Rhythm Metric-5 score, which measures the overall regularity of daily routines, but they did differ on the Composite Scale of Morningness, which measures preference for morning or evening hours; CI participants were significantly more "evening types." Consistent with previous epidemiological studies, CI had a greater number of chronic health conditions and used a greater number of medications on a regular basis.

3.2 Mean values and within-subject variability

Both CI and NI participants had substantial night-to-night variability in quantitative and qualitative sleep diary measures as well as actigraphy measures (Figures 1–3). Visual inspection suggested greater variability for CI than NI. Within-subject mean and standard deviation (variability) estimates for sleep diary and actigraphy measures, derived from mixed model comparisons of CI and NI groups, are shown in

Table 2. The comparison of mean values showed that the groups did not differ in mean bed time or rise time, and, contrary to expectations, CI had marginally shorter time in bed than NI. For the other sleep diary outcomes, CI had significantly "worse" values than NI. Actigraphy indicated no significant differences in group means, although the difference in mean total sleep time approached significance ($p = .08$). Within-subject variability measures showed *less* variability among CI for bed time but *greater* variability for wake time compared to NI. The groups did not differ in variability of overall time spent in bed. All other sleep diary measures showed significantly greater variability for the insomnia group. The CI group also showed greater variability in actigraphy measures of WASO and sleep efficiency.

3.3 Temporal patterning of sleep behaviors and sleep measures (Table 3)

We first examined temporal patterning for sleep diary measures. Among CI, none of the coefficients were significant for sleep latency, sleep efficiency, or sleep quality. Coefficients for Y_{t-2} , however, were significant for WASO (coefficient = +0.09, $p = .02$) and total sleep time (coefficient = +0.08, $p = .02$). These indicate that values for WASO and total sleep time on one night were significantly and positively correlated with values from two nights earlier. Among NI, none of the coefficients were significant for sleep latency, total sleep time, or sleep efficiency, indicating no serial dependence across nights. But coefficients for Y_{t-1} were significant for WASO (coefficient = +0.14, $p = .006$) and sleep quality (coefficient = +0.19, $p < .0001$). These indicate that values for WASO and sleep quality on one night were significantly and positively related to values from the previous night. As indicated by the small number of significant coefficients and their positive signs, sleep diary data for CI and NI did not support the hypothesis that poor sleep on one night is followed by better sleep on the next (or vice versa).

Parallel analyses were conducted for actigraphy data in each group. For the actigraphy data among CI, none of the coefficients were significant for sleep efficiency. Coefficients for Y_{t-2} were significant in a positive direction for sleep latency (coefficient = +0.07, $p = .05$) and total sleep time (coefficient = +0.07, $p = .05$), and the coefficient for Y_{t-3} was significant in a positive direction for WASO (coefficient = +0.07, $p = .04$). Among NI, none of the coefficients were significant for sleep latency or WASO. The coefficient for Y_{t-1} was significant in a negative direction for total sleep time (coefficient = -0.11, $p = .03$), and the coefficient for Y_{t-2} was significant in a positive direction for sleep efficiency (coefficient = +0.11, $p = .02$). In summary, actigraphy results for NI and CI generally indicate nonsignificant or positive coefficients among sleep variables for one night and the same sleep variable two or three nights earlier. Only one out of nine sleep diary or actigraphy sleep measures showed a significant negative relationship between successive nights in either group.

3.4 Clinical correlations with sleep variability

We restricted these analyses to the CI group only, given the exploratory nature of the analyses, our specific interest in insomnia, the small size of the NI group, and the “floor effects” in that group. Only one of 24 correlations was statistically significant at the .05 level: variability in bed time correlated positively with HAM-D score ($\rho = .41$, $p = 0.001$). Thus, there was no strong evidence to suggest that variability in sleep diary measures was related to overall sleep quality, sleepiness, or depressive symptoms.

4. DISCUSSION

Compared to individuals without sleep complaints, older adults with insomnia generally had both “worse” and more variable sleep as assessed by sleep diary. The exceptions were that participants with insomnia reported shorter time in bed and less variability of bed time than controls. Insomnia participants also had more variable WASO and sleep efficiency as measured by actigraphy. Sleep diary measures (WASO, sleep quality) positively correlated from one night to the next in the NI group, but no significant correlations, either positive or negative, were noted in CI. CI did have positive correlations for WASO and total sleep time between values for one night and corresponding values for the *two* previous nights. Values for actigraphy measures were weakly and positively correlated with values from two or three nights earlier in both groups, and only one negative association was observed. Thus, the hypothesis that a night of poor sleep is followed by a night of good sleep (or vice versa) was not supported. Finally, variability in diary and actigraphy sleep measures was not related to other clinical measures. In the aggregate, these findings suggest that increased variability of sleep may be an important characteristic of insomnia and an additional target for intervention.

Our findings are consistent with Wohlgemuth's earlier study, which showed that a greater number of nights are needed to derive stable estimates of both diary-rated and polysomnographic sleep in older adults with insomnia compared to controls (17). Vallières and colleagues found that the day-to-day variability of insomnia patients could be clustered into different patterns (6). It seems likely, based on these findings and our own, that non-insomnia controls would constitute a separate group or would predominantly cluster within the low-variability groups. Our approach was somewhat different from these earlier studies in that we directly compared measures of variability in CI and NI groups, rather than identifying measures of stability or subgroups of patients. We should also emphasize that the current study focused only on short-term variability of symptoms and sleep characteristics and did not address the longer-term variability of symptom type that has also been observed among insomnia patients (10).

The finding of greater variability pertained to all sleep diary measures that are beyond immediate volitional control, such as sleep latency, WASO, and total sleep time. Three other sleep diary measures, bed time, wake time, and time in bed, are clearly related to voluntary behavior. Behavioral models of insomnia suggest that poor sleep and sleep-incompatible voluntary behaviors may create a vicious cycle in chronic insomnia (1–4). However, CI actually showed *shorter* time in bed and *less* variability in bed time, which would tend to argue against their having globally worse “sleep hygiene” than NI. On the other hand, CI patients' greater regularity of bed time could be taken as evidence of their greater attention and intention to sleep, even when their ability to sleep is reduced (35). Moreover, the greater variability in wake times among CI could plausibly be interpreted as an attempt to “catch up” on sleep when the opportunity presents itself. Thus, patterns of sleep variability may provide useful evidence for behavioral models of insomnia.

Our findings with actigraphy also add to the previous observations made with sleep diary and PSG data. As is often the case in insomnia studies, both mean and variability measures showed fewer insomnia-control differences with actigraphy than with diary reports, although CI did have a trend toward shorter mean total sleep time and significantly greater variability on WASO and sleep efficiency compared to NI. Individuals with insomnia appear to experience (or report) their sleep according to criteria that do not directly map onto objective sleep methods such as PSG or actigraphy. The Wohlgemuth study and our own both suggest, however, that sleep variability in CI can be captured with objective methods. It should be noted, in this regard, that actigraphy data are not completely “objective,” nor free of potential self-report biases. Scoring algorithms such as Actiware relies on participant-specified bed times and rise times in order to determine the sleep interval and derived values for variables such as sleep latency and sleep efficiency.

We found only limited evidence that sleep diary variables on one night are related to variables from one, two, or three nights previously. The evidence we did find suggests positive rather than negative correlations across nights. Thus, a hypothesis based narrowly on homeostatic regulation of sleep—that a night of better sleep generally follows a night of worse sleep—was not strongly supported. We also recognize, however, that self-report and actigraphy measures of sleep are not sensitive measures of sleep homeostasis, which is best measured by examining slow wave activity in the sleep EEG (36). It is also possible that specific subgroups of patients, such as those identified by Vallières et al., have patterns of variability more consistent with the homeostatic hypothesis. Inspection of Figure 2b suggests this may be the case.

We did not find significant correlations between sleep diary variability and more global self-reports of sleep quality, sleepiness, or depression among CI. Qualitative research suggests that unpredictability of sleep is a common and frustrating component of the insomnia experience (7;37), but our findings indicate that this symptom is not strongly related to global sleep and

mood ratings. Thus, it may be useful to specifically include items specifically addressing sleep variability in new insomnia rating scales. The demonstration of substantial night-to-night variability may also have important implications for insomnia criteria that require subjects to meet a threshold criterion on a certain percentage of nights (38–40). For variables with a near-normal distribution, such as total sleep time, the mean value should provide the same classification as requiring a threshold value on 3 or more nights per week (i.e., half of a subject's values should be above the mean, and half below). But for variables characterized by large intra-subject variability, such as sleep latency or WASO, the mean value could yield very different classifications from those requiring a threshold value on 3 or more nights per week.

In future studies, it will also be important to more closely examine whether intra-subject variability decreases with behavioral or pharmacologic treatments. Treatment studies generally show smaller standard deviations for sleep diary variables following active interventions compared to control interventions (41;42), although the pattern varies considerably among specific sleep variables and specific studies. Some results actually suggest larger standard deviations on some variables such as total sleep time following treatment (43;44). We found only one study that statistically verified a reduction in standard deviation with behavioral treatment (45), but this study did not include a control group. It seems plausible that less variability, or conversely, greater predictability, would itself be seen as an improvement by many individuals suffering from insomnia (7).

Limitations of the current study include an exclusive focus on older adults. Short-term variability may show different patterns among younger or middle-aged adults. It is also possible that asking subjects to monitor their sleep behaviors affects those very behaviors, i.e., a type of Hawthorne effect. On the other hand, we feel fairly confident that subjects did not alter their behavior as a result of any therapeutic intervention since CI had long-term sleep problems and no intervention had been introduced. Finally, our metric of variability, within-subject standard deviation, is sensitive to the duration of measurement (in this case, two weeks). Thus, other metrics of variability should be considered.

In conclusion, we found that older individuals with insomnia have greater variability in diary and actigraphically-assessed sleep, that this variability does not have a strong temporal structure over successive days, and that it is not strongly related to other global clinical variables. Further examination of sleep variability may identify phenotypes that are distinct in other important ways, such as neurobiology or treatment response.

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Figure 1.

Variability across 14 days for sleep diary-assessed time in bed is shown for NI (Figure 1a) and CI (Figure 1b). Each individual's data across 14 nights is represented by a single line. Data from two extreme outlier nights in the NI group were excluded (Time in Bed > 1000 minutes).

Figure 2. Variability across 14 days for sleep diary-assessed sleep quality is shown for NI (Figure 2a) and CI (Figure 2b). Each individual's data across 14 nights is represented by a single line.

Figure 3. Variability across 14 days for actigraphy-assessed wake after sleep onset is shown for NI (Figure 3a) and CI (Figure 3b). Each individual's data across 14 nights is represented by a single line.

TABLE 1

DESCRIPTIVE SAMPLE CHARACTERISTICS

Variable	Chronic Insomnia N = 61	No Insomnia Control N = 31	Statistic ^I	p value
<i>Demographics</i>				
Age	71.4	70.7	-0.4	.7
Sex (% female)	67.2%	64.5%	X ² = 0.07	.8
Race (% Caucasian)	93.4%	100%	X ² = 2.1	.3
Subjective socioeconomic status	3.56	3.35	-0.6	.5
Education (n, %)				
High School or Less	11	5	18.0%	16.1%
Trade or Technical School	6	1	9.8%	3.2%
College	25	9	41.0%	29.0%
Post-graduate	19	16	31.2%	51.6%
<i>Sleep-wake and circadian</i>				
Pittsburgh Sleep Quality Index	10.3 (3.0)	2.3 (1.8)	-13.6	<.001
Epworth Sleepiness Scale	6.8 (3.9)	5.4 (3.0)	-1.8	.08
Composite Scale of Morningness	40.1(7.6)	44.3 (6.2)	2.7	.009
Social Rhythm Metric-5	4.84 (1.0)	5.14 (0.9)	1.4	.2
<i>Psychological status</i>				
Hamilton Rating Scale for Depression	9.5 (3.3)	3.3 (2.8)	8.7	<.001
Hamilton Rating Scale for Anxiety	5.6 (2.4)	1.7 (1.9)	7.7	<.001
Mini Mental State Exam	29.0 (1.0)	29.3 (0.9)	-1.7	.09
<i>Medical status</i>				
Number of chronic health conditions	5.6 (2.7)	4.9 (2.5)	-1.1	.3
Number of current medications	5.7 (3.2)	2.9 (1.4)	-4.0	<.001
SF-36 general health rating	69.1 (19.1)	82.0 (17.5)	3.1	.003

^I Statistics are t values unless otherwise specified.

TABLE 2
SLEEP DIARY AND ACTIGRAPHY VARIABLES ESTIMATED FROM MIXED MODELS^{1, 2}

Variable	Chronic Insomnia n = 61		No Insomnia Control n = 31		Statistic, p value	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
<i>Sleep Diary</i>						
Bed time (min from midnight)	-29.6	46.0	-34.3	70.9	0.33, 0.74	105, <0.0001
Morning rise time (min from 0700)	-3.62	66.0	0.39	40.7	-0.26, 0.79	108, <0.0001
Time spent in bed (min)	435.2	72.4	461.4	72.1	-2.23, 0.03	0.006, 0.94
Sleep latency (min) ³	34.1	36.1	11.0	21.1	6.68, <0.0001	48.3, <0.0001
Wake after sleep onset (min) ⁴	54.9	50.0	11.4	16.5	9.94, <0.0001	143, <0.0001
Total sleep time (min)	345.8	88.1	438.5	66.6	-7.80, <0.0001	36, <0.0001
Sleep efficiency (%) ⁵	79.1	14.9	95.4	4.8	13.7, <0.0001	36.3, <0.0001
Sleep quality (0-100)	51.4	19.3	81.2	11.6	-11.4, <0.0001	118, <0.0001
<i>Actigraphy</i>						
		N=51		N=29		
Sleep latency (min) ³	16.6	26.2	13.2	16.8	0.36, 0.72	2.32, 0.13
Wake after sleep onset (min) ⁴	52.1	22.6	47.2	19.3	0.86, 0.39	10.6, 0.0001
Total sleep time (min)	380.5	55.6	398.2	53.9	-1.79, 0.08	0.46, 0.50
Sleep efficiency (%) ²	81.7	7.0	83.3	5.6	0.66, 0.51	8.68, 0.003

¹ Variables are reported in original units. "Mean" represents the grand mean of individual within-subject mean values. "Standard Deviation" represents the grand mean of individual within-subject standard deviation values.

² Values are based on two weeks of data collection

³ log (x+1) transformation used for statistical analysis

⁴ square root transformation used for statistical analysis

⁵ log(100-x+1) transformation used for statistical analysis

TABLE 3
TEMPORAL PATTERNS OF SLEEP DIARY AND ACTIGRAPHY VARIABLES ESTIMATED FROM MIXED MODELS¹

Variable	Chronic Insomnia			No Insomnia Control		
	Y _{t-1}	Time lags ²		Y _{t-1}	Y _{t-2}	Y _{t-3}
<i>Sleep Diary</i>						
Sleep latency (min)						n = 31
Wake after sleep onset (min)					+0.14 p=.006	
Total sleep time (min)		+0.09 p=.02				
Sleep efficiency (%)		+0.08 p=.02				
Sleep quality (0–100)				+0.19 p<.0001		
<i>Actigraphy</i>						
Sleep latency (min) ³						N=29
Wake after sleep onset (min) ⁴						
Total sleep time (min)		+0.07 p=.05			-0.11 p=.03	
Sleep efficiency (%) ²			+0.07 p=.04			+0.11 p=.02

¹ Data in tables represent coefficient values from mixed model analyses, followed by p value. + indicates positive association between nights, - represents negative association between nights. Values are shown only for coefficients with p values ≤.05.

² Columns represent values for time lags of one night (Y_{t-1}), two nights (Y_{t-2}), or three nights (Y_{t-3}).