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Heart rate variability and daytime functioning in insomniacs and normal sleepers: Preliminary results☆

Su-Chang Fang[a], Chun-Jen Huang[b,c], Tsung-Tsair Yang[d,e], Pei-Shan Tsai[a,*]

[a]*College of Nursing, Taipei Medical University, Taipei, Taiwan*
[b]*Department of Anesthesiology, Mackay Memorial Hospital, Taipei, Taiwan*
[c]*Mackay Medicine, Nursing and Management College, Taipei, Taiwan*
[d]*Department of Psychiatry, Cardinal Tien Hospital, Hsin-Tien, Taipei, Taiwan*
[e]*College of Medicine, Fu-Jen Catholic University, Taipei, Taiwan*

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Abstract

Objectives: This study examined the differences in heart rate variability (HRV) and daytime functioning between insomniacs and normal sleepers. **Methods:** All participants underwent an interview, a medical examination, and a sleep measurement protocol during which they wore an actigraph and logged a sleep diary for a 7-day period to verify their eligibility. Included in the study were 18 insomniacs and 21 normal sleepers. During a laboratory session, these participants completed four paper–pencil tests of sleepiness, anxiety, fatigue, and concentration difficulty and the Wisconsin Card Sorting Test. Resting HRV was recorded under paced breathing. **Results:** Neither did insomniacs experience cognitive impairment nor did they experience excessive daytime sleepiness compared with normal sleepers. However, insomniacs experienced higher frequency of fatigue [effect size (ES)=1.14, *P*=.002] compared with normal sleepers. There was also a trend toward higher trait anxiety score (ES=0.62) and concentration difficulty (ES=0.59) in insomniacs than in normal sleepers. Although a tendency toward lower resting high-frequency (HF) HRV (ES=−0.57) in insomniacs than in normal sleepers was noted, neither the resting low-frequency (LF) HRV nor the LF/HF ratio were different between groups. Subjective sleep estimates correlated to self-reported daytime consequences such as fatigue and concentration difficulty but not cognitive function. On the contrary, objective sleep estimates correlated to problem-solving/conceptualization and learning but not self-reported daytime consequences. **Conclusions:** Insomniacs are not sleepier during the day than normal sleepers. However, they may experience such a daytime symptom as fatigue although cognitive function remains unimpaired.

Keywords: Autonomic nervous system; Cognitive function; Daytime functioning; Heart rate variability; Insomnia; Sleepiness

According to the criteria by the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (*DSM-IV*), patients with primary insomnia report impairment in daytime functioning as a result of their sleep difficulties [1]. Patients with insomnia often complain of daytime sleepiness [2,3], fatigue [2], impaired concentration [2,4], and/or impaired memory [4]. However, there have been inconsistent results across studies to definitively indicate a deficit in daytime functioning in primary insomniacs [5]. In particular, objective testing of daytime alertness such as the Multiple Sleep Latency Test has failed to detect differences in performance between people with insomnia and normal sleepers [6–8]. While objective data indicating a deficit in cognitive function have been shown in other types of sleep disorders such as narcolepsy and sleep apnea, objective data in insomnia have not revealed convincing evidence [9]. Moreover, very few studies have examined the performance of objective cognitive tests in insomnia, and the results

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* Corresponding author. Taipei Medical University, 250 Wu Hsing St., Taipei 110, Taiwan. Tel.: +886 2 27361661x6321; fax: +886 2 23772842.
E-mail address: ptsai@tmu.edu.tw (P.-S. Tsai).

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revealed that such cognitive functions as semantic memory [10], reaction time [11] and digit span [11], visual alertness, and selective attention [12] were affected, whereas no deficiencies were found in recent memory [10], divided attention [11], and the performance in the vigilance task [11]. The impact of insomnia on cognitive function thus warrants further investigations. We sought to answer the question of whether individuals with insomnia have impaired daytime functioning. To this end, we identified a group of individuals who truly suffered from insomnia and those who were truly free of sleep difficulties through a rigorous screening process and compared the differences in objective cognitive function [i.e., Wisconsin Card Sorting Test (WCST)], subjective daytime sleepiness, fatigue and difficulty in concentration between groups.

In addition to the question of whether insomniacs have impaired daytime functioning, physiological mechanisms responsible for the development of insomnia and its consequences (e.g., excessive daytime sleepiness, decreased daytime alertness, impaired cognitive function) are subjects of interest to sleep researchers. According to the hyperarousal theory of insomnia, people with insomnia might be in a state of constantly physiological, cognitive, and cortical hyperarousal [13–15]. The physiologic hyperarousal has been evidenced by elevated metabolic rate [16], cortisol levels [17,18], increased low-frequency (LF) heart rate variability (HRV), and decreased high-frequency (HF) HRV across all sleep stages [14]. These lead to the speculation that insomnia and its daytime consequences are associated with activation of the both arms of the stress system, the sympathetic−adrenal medullary (SA) system and the hypothalamic-pituitary-adrenal (HPA) axis. To date, there has been a paucity of studies on the autonomic nervous activity of primary insomniacs. Previous studies that tested the hypothesis of an activation of the stress system in insomnia have been mainly focused on the activity of the HPA axis or the SA system during the presleep or sleep period by examining evening or nocturnal cortisol and HRV [14,17,18]. This study was therefore set out to examine the differences in parameters of HRV between insomniacs and normal sleepers. We asked the questions of whether there is a basal activation of the sympathetic nervous system and whether the presumed sympathetic activation prevents individuals with insomnia from impaired daytime functioning that would normally be caused by sleep deprivation.

Methods

Measurements

Actigraphy

Objective sleep variables, including sleep onset latency (SOL), wake time after sleep onset (WASO), total sleep time (TST), and sleep efficiency (SE) were measured using a wrist actigraph (MicroMini Motionlogger Actigraph, Ambulatory Monitoring, Ardsley, NY, USA). The actigraph detects wrist movement through a piezoelectric accelerometer. The Zero-Crossing Mode (ZCM) was used to record the sleep estimates. Sleep estimation was performed using the Monionlogger data analysis software package (Action W-2, Ambulatory Monitoring). A previous study showed significant correlations for TST (r=.81) and SE (r=.55) derived from the Mini Motionlogger Actigraph using the ZCM and estimates derived from polysomnography [19].

Sleep diary

Sleep diary collects information on total time spent in bed (TTSIB), SOL, TST, and WASO. SE can be calculated using the formula SE=TST/TTSIB. Participants were asked to fill out the sleep diary as soon as they get out of the bed each morning for a consecutive 7-day period [20].

Chinese version of the Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index is a self-report questionnaire that assesses multiple dimensions of sleep over a 1-month time period [21,22]. Nineteen individual items generate seven “component” scores: subjective sleep quality, sleep latency, sleep duration, habitual SE, sleep disturbances, use of sleeping medication, and daytime dysfunction. The sum of the seven component scores yields one global score of subjective sleep quality (range 0–21); higher scores represent poorer subjective sleep quality. A Chinese version of the Pittsburgh Sleep Quality Index (CPSQI) has previously been developed and validated [20].

Fatigue and difficulty in concentration

Fatigue was measured by a single-item fatigue scale that asks the subject to report the frequency of fatigue due to poor sleep during a typical week (days/week). Difficulty in concentration was assessed by a single self-report item that asks the subject to indicate the frequency of difficulty in concentration on things to be done due to poor sleep during a typical week (days/week). The two scales were developed by Fichten at al. [23] in 1995.

The Epworth Sleepiness Scale

Epworth Sleepiness Scale (ESS) is a subjective self-report measurement of sleepiness. It measures the propensity to sleep under certain environmental conditions in daily life in the recent weeks [24]. There are eight items corresponding to eight conditions. These items are rated on a scale of 0–3 with a score of >10 indicating excessive daytime sleepiness (EDS). The Chinese version of the ESS has been validated in a previous study [25].

Spielberger State-Trait Anxiety Inventory—form Y2 (trait anxiety)

The Spielberger State-Trait Anxiety Inventory (STAI) is a self-administered, Likert-type instrument. It contains two separate 20-item scales that determine anxiety in a specific situation (form Y1) and as a trait character (form Y2) [26].

The state scale of the STAI evaluates how respondents feel at a particular moment and the trait scale refers to habitual tendency to be anxious over a long period of time. In this study, the trait scale was used.

Wisconsin Card Sorting Test

Wisconsin Card Sorting Test (WCST) is a computerized task that measures cognitive-executive function (WCST: CV4, Psychological Assessment Resources, Lutz, FL, USA). The test consists of 128 cards, each of which contains geometric figures that may vary along three dimensions (color, form, number). When performing the test, subjects are instructed to place each card below one of four target or key cards and to use some principle to guide them. They are not informed of the correct principle, but are told whether they are correct or incorrect after their placement of each card. The initial sorting principle is to match according to color. Once a criterion of 10 correctly sorted cards is attained, the principle is changed, although the subject is not informed of this change. The test proceeds until the subject has completed six sorting categories, each consisting of 10 consecutive cards matching the sorting principle in force, or has placed 64 cards in one category or, otherwise, has sorted all 128 cards. The WCST generates 11 item scores. In this study, 6 item scores were selected: preservative responses (%), preservative error responses (%), conceptual level responses (%), number of categories completed, failure to maintain set, and learning to learn. The lower the percentage of preservative responses and the number of categories completed and the higher the percentage of preservative error responses, the poorer the performance is. The percentage of conceptual level responses reflects the respondent's ability in cognitive conceptualization. The higher the failure to maintain set score, the lower the ability in maintaining preservative problem-solving strategy and concentration is.

Power spectral analysis of HRV

Electrocardiogram (ECG) signals were continuously monitored and simultaneously sampled at a sampling rate of 500 Hz using a data acquisition device with Acknowledge software (model MP100, Biopac Systems, Goleta, CA, USA) and saved to a personal computer for offline analysis with the use of a Biopac System ECG 100C preamplifier. Recordings of ECG were visually inspected for ectopic beats and artifacts, after which noise spikes were manually edited.

Frequency domain analysis of HRV was performed using standard software package (Nevrokard HRV Analysis software version 6.8.0, Slovenia) based on the nonparametric Fast Fourier Transformation algorithm. The measurements of HRV followed the standards suggested by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology in 1996 [27].

Two main spectral components: the LF (0.04–0.14 Hz) and HF (0.15–0.4 Hz), as well as total power (TP) were obtained in absolute power (ms^2). Due to large between-subject variability, nature logarithmic transformation was performed on these HRV parameters. The ratio of LF to HF was calculated and expressed as LF/HF.

Study procedure

Participant recruitment and eligibility screening

Participants were referrals from one family medicine clinic. Individuals who were able to read and write and aged from 19 to 65 years were screened for eligibility to participate in the study. Those who were diagnosed with psychiatric disorders or other sleep disorders, taking beta-adrenergic blocking agents, sympathetic agonists, or sleeping aids were excluded from the study. Shift workers, individuals who had traveled across time zones during the past 3 months prior to participation or experienced stressful events during the past week prior to participation, and individuals with chronic illness (e.g., cardiac ischemia, chronic obstructive pulmonary disease, asthma, esophageal-gastric reflux, gastric ulcer, chronic arthritis, chronic pain suffers, malignancy, dementia, seizure, multiple sclerosis, and Parkinson disease) that might cause pain or sleep difficulties were also excluded from participation. The Mini International Neuropsychiatric Interview [28]-Taiwan version 2.0.0 [29] was used to identify positive cases for any lifetime psychiatric disorder. After a thorough medical examination to rule out the exclusion conditions, those who met the *DSM-IV* diagnostic criteria for primary insomnia were referred to as potential insomniacs (n=29); those who did not meet the *DSM-IV* diagnostic criteria for primary insomnia were referred to as potential normal sleepers (n=34).

All potential subjects were screened for sleep quality with the CPSQI. Potential insomniacs with a CPSQI score of 5 or less (n=4) and potential normal sleepers with a CPSQI score of 6 or more (n=6) were excluded. Potential insomniacs who scored 6 or more on the CPSQI and potential normal sleepers who scored 5 or less were invited to participate in the study. A total of 25 potential insomniacs and 28 potential normal sleepers were recruited.

Data collection

Written informed consents were obtained from all participants. All participants underwent a sleep measurement protocol during which they wore a wrist actigraph for 3 days and logged a 7-day sleep diary during a 7-day period. Insomniacs were defined as those who met at least one of the following criteria on both actigraphy and diary measures: (1) WASO >30 min, (2) TST ≤6.5 h, and (3) SE ≤85%. Normal sleepers were defined as those who met all of the following criteria on both actigraphy and diary measures: (1) WASO ≤30 min, (2) TST >6.5 h, and (3) SE >85%. Thirteen individuals did not meet the definitions of insomniacs (n=6) or normal sleepers (n=7) and were not included in the data analysis.

In the end, included in the study were 39 participants—18 insomniacs and 21 normal sleepers. The participants were required to abstain from drinking caffeinated or alcohol-containing beverage starting at least 3 h prior to testing.

Table 1
Demographic data of study participants (n=39)

	Insomniacs (n=18)	Normal Sleepers (n=21)	P
Age (years, mean±S.D.; range)	34.16±14.46; 20–63	27.81±8.67; 20–50	.093
Sex (n, %)			1.00
Male	6 (33.3)	7 (33.3)	
Female	12 (66.7)	14 (66.7)	
Marital status (n, %)			.748
Not married	12 (66.7)	15 (71.4)	
Married	6 (33.3)	6 (28.6)	
Annual income (n, %)			.229
<240 000 NT	5 (29.4)	12 (57.1)	
240-600 000 NT	9 (52.9)	7 (33.3)	
>600 000 NT	3 (17.6)	2 (9.5)	
Naps (n, %)			.338
<1/week	2 (11.1)	2 (9.5)	
1–4/week	6 (33.3)	3 (14.3)	
>4/week	10 (55.6)	16 (72.6)	
Exercise (n, %)			.975
<1/week	8 (44.4)	10 (47.6)	
1–4/week	8 (44.4)	9 (42.9)	
>4/week	1 (11.1)	2 (9.5)	
Coffee consumption (n, %)			.667
<1/week	14 (77.8)	15 (71.4)	
1–4/week	3 (16.7)	3 (14.3)	
>4/week	1 (5.6)	3 (14.3)	
Smoking (n, %)			.117
Smokers	2 (11.1)	0 (0)	
Nonsmokers	16 (88.9)	21 (100.0)	
Alcohol consumption (n, %)			.348
<1/week	18 (100.0)	20 (95.2)	
1–4/week	0 (0.0)	1 (4.8)	
Bed time (mean±S.D.)	24.36±1.36	24.86±1.25	.24
(Clock time)	0:22	0:52	
Wake time (mean±S.D.)	7.66±1.67	8.72±1.37	.03
(Clock time)	7:40	8:43	

These 39 participants all underwent an afternoon session. The participants were continuously monitored during the afternoon session to ensure that they remained awake. All laboratory sessions were conducted between 14:00 and 17:00. Briefly, the participants completed the Fatigue and Concentration Difficulty Scales, ESS, and STAI-form Y2. After completion of these paper–pencil tests, the participants were allowed to rest for 10 min by sitting quietly while maintaining their eyes open. Then 5-min recordings of HRV under paced breathing were obtained from all participants. For the measurement of HRV, precordial ECG was measured via three skin sensors placed in the standard Lead II position. Before recording the ECG, the participants practiced controlling their breathing rhythm to follow the metronome. During the ECG recording, participants were resting in a supine position and breathing in a controlled rate of 12–15 breaths per min. After the HRV recording, the participants performed the WCST for approximately 10–15 min.

Statistical procedure

The chi-square test or Fisher's Exact test was performed to compare categorical data between the insomniac group and the control group. The independent t test was used to examine the group differences in continuous data. For group comparisons in major variables of interest, we calculated Cohen's d to determine the effect size (ES). Cohen's d indicates how different (ES) between groups a variable of interest is [30]. A medium ES (d=0.5) was a considerable group difference. The paired t test and the Bland–Altman analysis were performed to examine the agreement between objective and subjective measurements of sleep. With the Bland–Altman analysis, the limits of agreement between measurements were calculated as the mean difference ±1.96 standard deviations. Correlations between sleep variables and measurements of daytime consequences were performed using the Pearson correlation analysis. Post hoc sample size calculation was also performed to determine the number of subjects needed to achieve significant group differences.

Results

Demographics, lifestyle factors, and sleep variables between insomniacs and normal sleepers

The insomniacs and normal sleepers were not significantly different in demographic and lifestyle variables, nor did they differ in the number of naps per week (see Table 1).

Table 2
Comparison of sleep variables between insomniacs and normal sleepers (n=39)

	Insomniacs (n=18) (mean±S.D.)	Normal sleepers (n=21) (mean±S.D.)	t	95% CI of difference	P
CPSQI	11.78±2.18	3.52±1.56	13.691	7.03–9.47	<.001
Sleep diary [a]					
SOL (min)	44.48±48.69	11.00±5.77	3.134	11.81–55.15	.003
WASO (min)	17.30±20.44	4.44±6.44	2.728	3.30–22.42	.010
TST (min)	347.74±63.21	456.69±42.05	−6.358	−143.69 to −74.19	<.001
SE (%)	79.95±11.21	96.60±2.49	−6.623	−21.73 to −11.54	<.001
Actigraphy [b]					
SOL (min)	25.16±25.49	4.79±3.57	3.628	8.98–31.74	.001
WASO (min)	32.29±16.33	11.88±8.10	5.023	12.16–28.64	<.001
TST (min)	373.02±61.46	443.99±47.06	−4.032	−1.06 to −35.27	<.001
SE (%)	90.18±4.75	96.94±2.14	−5.839	−9.11 to −4.41	<.001

[a] Sleep variables were computed by averaging the 7-day values obtained from the diaries.
[b] Sleep variables were computed by averaging the 3-day values derived from the actigraphy.

However, the insomniac group has a wider age range than that of the normal sleepers. The average habitual bedtime was comparable between groups. The insomniac group got up earlier in the morning compared with the normal sleepers (see Table 1). As expected, the two groups significantly differed in all sleep variables including SOL, WASO, TST, and SE derived either from the sleep diary or from the actigraphy (Table 2).

The agreement between objective and subjective measurements of sleep

Results from Pearson correlation revealed that all sleep variables derived from the sleep diary correlated moderately with those measured by the actigraphy (r=.56, .40, .72, and .63, respectively; all P<.05). The agreement between objective and subjective measurements was assessed using the Bland–Altman analysis. Results from the Bland-Altman analysis revealed that the limits of agreement of all sleep variables between objective and subjective measurements were large and not clinically acceptable (SOL: −48 to 72.7 min; WASO: −47.3 to 25. 5 min; TST: −109.6 to 100 min; SE: −25.2% to 15.3%). The agreement of SE between the subjective and objective measurements was also assessed in insomniacs and normal sleepers separately using a paired t test. In insomniacs, the actigraphy-measured SE was significantly higher than that derived from the diary (P=.004), whereas in normal sleepers, the actigraphy-measured SE was not significantly different from the diary-derived SE (P=.617).

The relationships between actigraphy-measured sleep variables and parameters of daytime functioning

Actigraphy TST was not related to the frequency of fatigue, the frequency of concentration difficulty, and the ESS score (r=−.088, .002, and .05, respectively; P=.641, .137, and .763, respectively). Similarly, actigraphy SE was unrelated to fatigue, concentration difficulty, and ESS (r= −.077, −.242, and .087, respectively; P=.641, .137, and .597, respectively). However, actigraphy-measured TST correlated to failure to maintain set (r=−.349, P=.03); actigraphy-measured SE correlated to learning to learn (r=.423, P=.016).

The relationships between diary-derived sleep variables and parameters of daytime functioning

Diary TST correlated to the frequency of fatigue (r= −.468, P=.003) but neither did it significantly correlate to concentration difficulty nor did it correlate to ESS (r=.259 and .092, respectively; P=.111 and .577, respectively). Diary SE correlated to both the frequency of fatigue (r=−.72, P<.001) and concentration difficulty (r=−.418, P=.008) but not ESS (r=−.054, P=.746). On the contrary, diary-derived TST and SE were not significantly correlated with any one of the WCST variables (all P>.05).

The relationships between trait anxiety score and parameters of daytime functioning

Trait anxiety score positively correlated to the frequency of fatigue (r=.32, P=.046) but not the frequency of difficulty

Table 3
Comparison of anxiety, daytime sleepiness, fatigue and concentration difficulty between insomniacs and normal sleepers

	Insomniacs (n=18)	Normal sleepers (n=21)	ES (Cohen's d)	P [a]
Trait-Anxiety	46.7±8.9	40.7±10.5	0.62	.067
ESS	8.16±4.36	7.38±3.35	0.20	.529
Fatigue (day/week)	2.75±2.17	0.83±0.97	1.14	.002
Concentration difficulty (day/week)	0.80±0.89	0.35±0.61	0.59	.073

Values are expressed as mean±S.D.
[a] Group difference by t test.

Table 4
Comparison of the WCST item scores between insomniacs and normal sleeper

Variables	Insomniacs (n=18)	Normal sleepers (n=21)	ES (Cohen's d)	P [a]
Preservative responses (%)	41.89±11.70	42.43±13.25	−0.04	.894
Preservative errors (%)	41.06±11.07	42.05±12.81	−0.08	.799
Conceptual level responses (%)	38.89±10.05	42.38±12.33	−0.31	.344
No. of categories completed	4.39±2.25	4.67±2.18	−0.13	.698
Failure to maintain set	1.00±1.60	0.71±1.00	0.22	.504
Learning to learn	0.97±5.74	1.79±4.41	−0.16	.650

Values are expressed as mean±S.D.

[a] Group difference by t test.

in concentration and ESS (P=.334 and .107, respectively). Trait anxiety was not significantly related to any one of the WCST item score (all P>.05).

Measures of daytime functioning, anxiety, and executive-cognitive function between insomniacs and normal sleepers

The percentage of individuals experiencing EDS (ESS >10) was not significantly different between insomniacs and normal sleepers (28% vs. 20%, P=.395). The differences in daytime sleepiness as assessed by the ESS were not statistically different between groups and the ES for the group difference in ESS was small (Table 3). Trait anxiety was not statistically significant between groups, but there was a medium ES for the group difference (Table 3).

Daytime consequences in terms of days of fatigue and difficulty in concentration per week were also compared between groups (Table 3). Insomniacs had significantly more days experiencing fatigue during a week compared with normal sleepers (ES=1.22; P=.002). Days of difficulty in concentration per week were not significantly different between groups although the ES for the between-group difference was medium.

In terms of the executive–cognitive function, all six WCST item scores were not significantly different between groups and the ESs for the group differences were small (Table 4).

HRV between insomniacs and normal sleepers

The comparison of the frequency domain parameters of HRV did not reveal statistically significant differences between groups (Table 5). However, it should be noted that the ES of the between-group difference in HF HRV was 0.57.

Post hoc sample size calculations revealed that 31 subjects per group (n=62) are required to achieve a group difference in the HF HRV score for a two-sided test, with the significance level at .05 and power of 80%.

Discussion

In this study, insomniacs and normal sleepers were identified through 3 phases of screening using both subjective and objective indicators. Our intention was to identify a group of individuals who truly suffered from insomnia and those who were truly free of insomnia to better answer the question of whether insomniacs have impaired daytime functioning. In our sample, individuals with insomnia took longer time to fall asleep, experienced more wake time after sleep onset, and had shorter sleep duration and worse SE compared with normal sleepers both in subjective and objective assessments. In terms of daytime consequences, neither did insomniacs experience EDS nor did they experience cognitive impairment (as determined by the WCST) as compared with normal sleepers. However, insomniacs did experience more days suffering from fatigue and had a tendency toward higher trait anxiety score and concentration difficulty during a typical week. These findings are consistent with results from previous studies that insomniacs experience an increase in fatigue but not in sleepiness [5,31]. The ESs for the between-group differences in fatigue and concentration difficulty were comparable to those observed in a previous study comparing poor sleepers and insomniacs in older adults and college students and that fatigue is the most significantly impaired daytime function among all [2]. The other question we sought to answer was

Table 5
Comparison of parameters of HRV between insomniacs and normal sleepers

	Insomniacs (n=18)	Normal sleepers (n=21)	ES (Cohen's d)	P [b]
Ln LF [a] (ms^2)	6.12±0.75	6.22±1.03	−0.12	.737
Ln HF [a] (ms^2)	6.31±0.93	6.91±1.15	−0.57	.087
Ln TP [a] (ms^2)	7.68±0.73	7.85±0.86	−0.21	.502
LF/HF	1.06±0.74	0.93±1.14	0.16	.688

Values are expressed as mean±S.D.; Ln - nature logarithm.

[a] Values were nature log-transformed.

[b] Group difference by t test.

whether altered resting HRV is associated with insomnia. Although findings from this study revealed that insomniacs had a tendency toward lower resting HF HRV as compared with normal sleepers, neither LF HRV nor LF/HF ratio was different between groups. This study therefore does not clearly strengthen the case for the sympathetic hyperarousal hypothesis of insomnia.

In this study, objective sleep estimates moderately correlated with subjective estimates of sleep; however, the agreement of the two was poor. Because sleep needs vary from person to person, subjective measurements of sleep constitute an important part in the evaluation of sleep quality. However, our data seems to suggest that insomniacs tend to overestimate their sleep difficulties as the diary-derived SE was significantly lower than the actigraphy-measured SE. In addition, subjectively measured sleep variables correlated to self-reported daytime consequences such as fatigue and concentration difficulty but not cognitive function determined by the WCST. Similarly, trait anxiety correlated to self-reported frequency of fatigue but not cognitive function determined by the WCST. On the contrary, objectively measured sleep variables correlated to problem-solving/conceptualization (i.e., failure to maintain set score) and learning (i.e., learning to learn score) but not subjectively measured daytime consequences. Together, these data suggest that subjective perception of impairment in daytime functioning is maintained or further exacerbated, at least in part, by misperception of nighttime sleep. “Real” impairment in daytime functioning, on the other hand, is not apparent unless impaired nighttime sleep is objectively detectable.

There were several limitations in this study. First, this study is limited by its small sample size and therefore might be underpowered to detect significant group differences. Second, measurements of HRV were obtained under paced breathing during the midday. It has been suggested that HF HRV may be enhanced by paced breathing [32], and as there is a circadian rhythm of HF HRV [33], these results may not necessarily generalize to other times of the day. Third, the two comparison groups differed in their age range, with the insomniac group having a wider age range. Thus, the possible impact of age on the results of daytime functioning and HRV cannot be ruled out. Nevertheless, using a rigorous screening protocol, the insomniac group and the control group included in this study should be representative of their respective populations (i.e., insomniacs and normal sleepers). We found that individuals with insomnia are not sleepier than normal sleepers during the day. However, they may actually experience such a daytime symptom as fatigue, although cognitive function remains unimpaired.

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References

[1] American Psychiatric Association. Diagnosis and Statistical Manual of Mental Disorders. 4th ed. Washington, DC: American Psychiatric Association; 1994.
[2] Alapin I, Fichten CS, Libman E, Creti L, Bailes S, Wright J. How is good and poor sleep in older adults and college students related to daytime sleepiness, fatigue, and ability to concentrate? J Psychosom Res 2000;49:381–90.
[3] Moul DE, Nofzinger EA, Pilkonis PA, Houck PR, Miewald JM, Buysse DJ. Symptom reports in severe chronic insomnia. Sleep 2002; 25:553–63.
[4] Roth T, Ancoli-Israel S. Daytime consequences and correlates of insomnia in the United States: results of the 1991 National Sleep Foundation Survey. II. Sleep 1999;22(Suppl 2):S354–S358.
[5] Riedel BW, Lichstein KL. Insomnia and daytime functioning. Sleep Med Rev 2000;4:277–98.
[6] Seidel WF, Ball S, Cohen S, Patterson N, Yost D, Dement WC. Daytime alertness in relation to mood, performance, and nocturnal sleep in chronic insomniacs and noncomplaining sleepers. Sleep 1984; 7:230–8.
[7] Stepanski E, Zorick F, Roehrs T, Young D, Roth T. Daytime alertness in patients with chronic insomnia compared with asymptomatic control subjects. Sleep 1988;11:54–60.
[8] Bonnet MH, Arand DL. Activity, arousal, and the MSLT in patients with insomnia. Sleep 2000;23:205–12.
[9] Roth T, Costa e Silva JA, Chase MH. Sleep and cognitive (memory) function: research and clinical perspectives. Sleep Med 2001;2:379–87.
[10] Mendelson WB, Garnett D, Gillin JC, Weingartner H. The experience of insomnia and daytime and nighttime functioning. Psychiatry Res 1984;12:235–50.
[11] Hauri PJ. Cognitive deficits in insomnia patients. Acta Neurol Belg 1997;97:113–7.
[12] Schneider C, Fulda S, Schulz H. Daytime variation in performance and tiredness/sleepiness ratings in patients with insomnia, narcolepsy, sleep apnea and normal controls. J Sleep Res 2004;13:373–83.
[13] Perlis ML, Giles DE, Mendelson WB, Bootzin RR, Wyatt JK. Psychophysiological insomnia: the behavioural model and a neurocognitive perspective. J Sleep Res 1997;6:179–88.
[14] Bonnet MH, Arand DL. Heart rate variability in insomniacs and matched normal sleepers. Psychosom Med 1998;60:610–5.
[15] Cortoos A, Verstraeten E, Cluydts R. Neurophysiological aspects of primary insomnia: implications for its treatment. Sleep Med Rev 2006; 10:255–66.
[16] Bonnet MH, Arand DL. 24-hour metabolic rate in insomniacs and matched normal sleepers. Sleep 1995;18:581–8.
[17] Vgontzas AN, Bixler EO, Lin HM, Prolo P, Mastorakos G, Vela-Bueno A, Kales A, Chrousos GP. Chronic insomnia is associated with nyctohemeral activation of the hypothalamic-pituitary-adrenal axis: clinical implications. J Clin Endocrinol Metab 2001;86:3787–94.
[18] Rodenbeck A, Huether G, Ruther E, Hajak G. Interactions between evening and nocturnal cortisol secretion and sleep parameters in patients with severe chronic primary insomnia. Neurosci Lett 2002; 324:159–63.
[19] Jean-Louis G, Mendlowicz MV, Gillin JC, Rapaport MH, Kelsoe JR, Zizi F, Landolt H, von Gizycki H. Sleep estimation from wrist activity in patients with major depression. Physiol Behav 2000;70:49–53.
[20] Tsai PS, Wang SY, Wang MY, Su CT, Yang TT, Huang CJ, Fang SC. Psychometric evaluation of the Chinese version of the Pittsburgh Sleep Quality Index (CPSQI) in primary insomnia and control subjects. Qual Life Res 2005;14:1943–52.
[21] Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193–213.
[22] Buysse DJ, Reynolds CF, Monk TH, Hoch CC, Yeager AL, Kupfer DJ. Quantification of subjective sleep quality in healthy elderly men and

women using the Pittsburgh Sleep Quality Index (PSQI). Sleep 1991; 14:331–8.
[23] Fichten CS, Creti L, Amsel R, Brender W, Weinstein N, Libman E. Poor sleepers who do not complain of insomnia: myths and realities about psychological and lifestyle characteristics of older good and poor sleepers. J Behav Med 1995;18:189–223.
[24] Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep 1991;14:540–5.
[25] Chen NH, Johns MW, Li HY, et al. Validation of a Chinese version of the Epworth Sleepiness Scale. Qual Life Res 2002;11:817–21.
[26] Spielberger CD. State-Trait Anxiety Inventory for Adults: manual, test, scoring key. Redwood City (Calif): Mind Garden; 1983.
[27] Task Force of the European Society of Cardiology, North American Society of Pacing and Electrophysiology. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Circulation 1996;93:1043–65.
[28] Sheehan DV, Lecrubier Y, Sheehan KH, et al. The Mini-International Neuropsychiatric Interview (M.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for *DSM-IV* and ICD-10. J Clin Psychiatry 1998;59(Suppl 20):22–33.
[29] Taiwanese Society of Psychiatry. The Mini International Neuropsychiatric Interview (MINI) Taiwan version 2.0.0. Taipei, Taiwan: Taiwanese Society of Psychiatry; 2001.
[30] Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale (NJ): Lawrence Earlbaum Associates; 1998.
[31] Lichstein KL, Wilson NM, Noe SL, Aguillard RN, Bellur SN. Daytime sleepiness in insomnia: behavioral, biological and subjective indices. Sleep 1994;17:693–702.
[32] Pagani M, Lombardi F, Guzzetti S, Rimoldi O, Furlan R, Pizzinelli P, Sandrone G, Malfatto G, Dell'Orto S, Piccaluga E, et al. Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympatho-vagal interaction in man and conscious dog. Circ Res 1986;59:178–93.
[33] van Eekelen AP, Houtveen JH, Kerkhof GA. Circadian variation in base rate measures of cardiac autonomic activity. Eur J Appl Physiol 2004;93:39–46.