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Original Article

Deficits in attention performance are associated with insufficiency of slow-wave sleep in insomnia

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ABSTRACT

Objective: Cognitive impairment is associated with insomnia. However, there is a lack of evidence suggesting a link between insomnia and cognitive dysfunction in objective testing. The objectives of our current study were to assess the differences in components of attentional performance between primary insomnia patients and normal-sleeping controls and to examine potential predictors of attention impairment in patients with insomnia.
Methods: We studied 36 patients (age 40.39 ± 12.36 years; 57.1% male) with insomnia and 25 normal-sleeping controls (age 39.88 ± 12.50 years; 52.9% male) who underwent one-night polysomnography followed by Multiple Sleep Latency Test (MSLT) and Attention Network Task (ANT). ANT reflected three attentional networks termed the alerting, orienting, and executive control networks.
Results: After controlling for age, gender, body mass index, depression, anxiety, and education levels, patients with insomnia scored higher on the executive control variable of the ANT compared with normal-sleeping controls (96.75 ± 7.60 vs. 57.00 ± 10.49, $p = 0.01$). This higher score was independently associated with insufficiency of slow-wave sleep during nighttime sleep ($\beta = -0.38$, $p = 0.04$).
Conclusion: Our findings suggest that insomnia is associated with deficits in executive control of attention and that the underlying mechanism may be insufficiency of slow-wave sleep in chronic insomnia.

1. Introduction

Insomnia is the most prevalent sleep disorder in the general population. One-fourth to one-third of the general population reports difficulty falling or staying asleep [1–8], and approximately 10% presents with chronic complaints and seeks medical help for insomnia [9,10].

It has been shown that cognitive impairment (ie, impairment of attention and concentration) is associated with insomnia [11–15], although studies assessing objective measurements of neuropsychological performance in insomnia patients have shown inconsistent results. Patients with insomnia exhibit selective and relatively low-grade cognitive deficits, or no deficit, compared to controls [14,16–26]. Inconsistent findings in the objective evaluation for cognitive impairment among insomnia patients may be related to the heterogeneity of subjects and the use of insensitive measures to detect mild impairment. Furthermore, specific differences in terms of subdomains of cognitive performance between insomnia patients and normal-sleeping controls have been inconsistent across studies. Recently, a meta-analysis has shown mild-to-moderate magnitude differences between patients with insomnia and normal sleepers in working memory, episodic memory, and problem solving, but no differences in other components of attention (eg, alertness, divided attention) [14].

Attention impairment is one of the most common complaints of cognitive impairment in patients with insomnia; however, little is known about how sleep architecture and other sleep variables affect various aspects of attentional functions. Previous studies have suggested that decreased detectability (the ability to detect targets from non-targets in attentional testing) [27] is associated with shorter self-reported sleep duration [28], and increase in the frequency of perseveration errors (a reaction time below 100 ms) [27] is associated with shorter objective sleep duration, higher number of objective awakenings, and higher electroencephalogram (EEG) alpha relative power in patients with insomnia [28]; insomnia with short objective sleep duration is associated with set-switching

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attention impairment [23]. A study by Bazil et al. suggested that improvement in attention was accompanied by increased slow-wave sleep (SWS) and decreased non-rapid-eye-movement sleep stage 1 (NREM 1) in epilepsy patients with insomnia after pregabalin treatment [29]. Crenshaw and Edinger also suggested that relatively slow reaction times were associated with slow-wave power in the 2- to 4-Hz EEG frequency band in elderly insomniacs but not in normal controls [25]. However, the association between SWS and cognitive function was complex and inconclusive in middle-aged insomnia patients and controls [26].

Human attention has been described as comprising three main networks, termed the 'alerting,' 'orienting,' and 'executive control' networks, which are associated with independent brain circuits and neuromodulators [30,31]. Alerting is defined as the ability to achieve and sustain alertness, orienting is defined as the selection of information from sensory input, and executive control is associated with functions of conflict resolution [30]. The Attention Network Task (ANT) is a measure of assessing the alerting, orientating, and executive control of human attention within a single task [32]. To the best of our knowledge, only one previous study has used ANT as a measure of attentional function in primary insomnia patients, showing insomnia with shorter Multiple Sleep Latency Test (MSLT) values was associated with longer overall reaction time (RT) compared to normal-sleeping controls [33]. Thus, the objectives of the present study were to (1) assess the independent differences of distinct attentional components between primary insomnia patients and normal-sleeping controls and (2) evaluate the potential predictors, including clinical and sleep characteristics, of attention impairment in insomnia patients.

2. Methods

2.1. Subjects

This was a between-groups and cross-sectional design study conducted at the Sleep Medicine Center, West China Hospital of Sichuan University, China. Patients with insomnia and normal-sleeping controls matched for age and gender comprised the study sample. This study was approved by the Research Ethics Board of the West China Hospital of Sichuan University and informed consent was obtained from each participant.

All patients with insomnia were adults (age > 18 years) recruited from the Sleep Clinic, West China Hospital of Sichuan University. Normal-sleeping controls were recruited from college students and their relatives, as well as from the medical and technical staff and visitors of West China Hospital with posted announcements during the same period. A complete medical history and physical examination including mental status assessment was performed. All potential research subjects were interviewed with a comprehensive questionnaire. The questionnaire gathered any history of sleep complaints, general health issues, and medication use. Patients with insomnia met Diagnostic and Statistical Manual for Mental Disorders (DSM-IV-TR) criteria for primary insomnia [34] and scored ≥7 on the Chinese version of Pittsburgh Sleep Quality Index (CPSQI) [35]. We selected 7 as the cut-off criterion because CPSQI > 6 has been shown to differentiate normal and sleep disturbance better than CPSQI > 5 in the Chinese population [35]. In order to ensure the chronicity of symptoms, the insomnia patients were also required to have reported at least a six-month duration of insomnia symptoms instead of the one-month minimum required by the DSM-IV-TR. Furthermore, patients with insomnia agreed to abstain from sedatives for at least two weeks before the study. Control subjects were adults who reported no sleep complaints, had PSQI scores ≤4, and had no major medical or psychiatric conditions based on history and physical examinations.

During the recruitment period, after an overnight polysomnography (PSG) followed by a standard MSLT study in our sleep laboratory, 36 patients with insomnia and 25 normal controls met the selection criteria for the present study. The normal-sleeping control and insomnia groups were similar in terms of age (39.88 ± 12.50 and 40.39 ± 10.36 years, respectively) and gender (53% and 57% male, respectively).

2.2. Polysomnography

All subjects were evaluated for one night in the sleep laboratory in sound-attenuated, light- and temperature-controlled rooms. During this evaluation, subjects were allowed to sleep ad libitum based on their habitual sleep time, with the majority of the subjects recorded from 22:00–23:00 to 06:00–07:00. Subjects were continuously monitored with 16-channel polygraphs including EEG, bilateral electrooculography, electromyography, and electrocardiography. All sleep parameters recorded by PSG were analyzed according to the international criteria of American Academy of Sleep Medicine [36] by a senior technician who was blinded to any diagnosis. Sleep continuity parameters, assessed from the sleep recordings, included sleep onset latency, wake after sleep onset (WASO), total sleep time (TST), time in bed (TIB), and sleep efficiency (TST/TIB * 100).

2.3. Depressive symptoms

Depressive symptomatology was assessed both clinically and using the Beck Depression Inventory (BDI). None of the subjects met the criteria for a current episode of major depressive disorder based on assessment by a psychiatrist. Two insomnia patients scored above the recommended cutoff point above 19 for moderate depression. All scores of good sleeping controls were less than 10. Given that BDI includes items relating to sleep complaints and in order to exclude subjects with severe depressive symptoms even if they do not meet the criteria for a current episode of major depressive disorder, we chose BDI ≥ 30, severe depression, as an exclusion criterion in our study.

2.4. Anxiety symptoms

Anxiety symptomatology was assessed by State-Trait Anxiety Inventory for Adults™ (SAI and TAI) [37]. The temporary condition of 'state anxiety' and the general and long-standing quality of 'trait anxiety' were assessed.

2.5. Other key measurements

PSQI was used to assess sleep quality over a one-month time interval. Higher total scores of PSQI indicate poorer sleep quality [38]. Objective and subjective daytime sleepiness were measured by MSLT [39,40] and Epworth Sleepiness Scale (ESS) [41] in the sleep laboratory, respectively. Lower values of mean MSLT [39,40] and higher values of ESS scores [41] indicated more severe objective and subjective daytime sleepiness, respectively. Body mass index (BMI) was based on measured height (cm) and weight (kg) during the subjects' sleep laboratory visits. The subjects were advised to refrain from smoking or drinking caffeine or alcohol on the test day.

2.6. ANT

ANT was administered by E-prime software [42] (Fig. 1) [33] in the morning (09:30–10:30 h) following PSG recording in the sleep laboratory. The test consisted of 24-trial full-feedback practice blocks and three experimental blocks of trials with no feedback. Each experimental block consisted of 96 trials (4 cue conditions × 2 target