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Original Article

Daytime sleepiness associated with poor sustained attention in middle and late adulthood

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ABSTRACT

Objective: We aimed to determine the association between psychomotor vigilance task (PVT) performance and sleep-related factors including sleep duration, daytime sleepiness, poor sleep quality, insomnia, and habitual snoring in a population-based sample.
Methods: This was a cross-sectional analysis from the ongoing prospective cohort study, the Korean Genome and Epidemiology Study. We measured PVT performance and documented demographics, sleep-related factors, life style, and medical conditions in community dwelling adults (N = 2499; mean age 57.1 ± 7.3; male 1259). Associations between PVT parameters and sleep-related factors were tested, adjusting for age, gender, smoking, alcohol use, education, body mass index, hypertension, diabetes, depression, and the interval between mid-sleep time and PVT test.
Results: High Epworth Sleepiness Scale (ESS, ≥8) was associated with slower mean reciprocal response speed (mean RRT) (3.69 ± 0.02 vs. 3.77 ± 0.01, $p < 0.001$), higher probability for increased lapses (≥4) (OR 1.48, CI 1.12–1.88, $p = 0.001$), and more negative RRT slope (–0.036 ± 0.002 vs. –0.030 ± 0.001, $p = 0.02$). Older age, female gender, low education level, depressive mood, and the interval between mid-sleep and PVT test were also associated with poor performance. Sleep duration, habitual snoring, insomnia, or poor sleep quality (the Pittsburgh Sleep Quality Index score > 5) was not related to PVT parameters.
Conclusions: At the population level, our results revealed important modifiers of PVT performance, which included subjective reports of daytime sleepiness.

1. Introduction

An adequate amount sleep and good quality sleep are essential in maintaining sufficient attention and cognitive performance during wakefulness. However, in modern society, a significant number of people suffer from insufficient sleep or sleep disorders such as insomnia and obstructive sleep apnea [1–4]. Sleep disorders, as well as insufficient sleep, are known to impair daytime functioning in both experimental and clinical settings [5,6]. Recently, several epidemiologic or community-based studies have explored the association between short sleep duration and sleep-related complaints such as daytime sleepiness, snoring, insomnia and poor sleep, with impaired cognitive performance [7–12]. One previous study has measured psychomotor speed with response time in simple and multiple-choice tests [7]. A U-shaped association between self-reported sleep duration and psychomotor speed was reported; however, the relationship between sleep complaints and psychomotor slowing was not reported [7].

Whereas simple and multiple-choice tests are mainly used in cognitive epidemiology studies [13,14], the 10-min psychomotor vigilance task (PVT) is the most extensively studied measure of sustained attention in sleep research [15–17]. The PVT protocol is simple to perform with hand-held portable devices and, thus, has a

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potential to be easily administered as a repeated measure of psychomotor functioning in any prospective epidemiologic cohort study. The PVT measures responses to randomly presented stimuli of sufficient test load, up to 100 stimuli per trial [15–17]. The PVT has several advantages over other cognitive tests: it is highly sensitive to sleep loss, demonstrates high intra-class coefficient on repeated testing, and is less likely to be confounded by the learning effects [5,16–18]. It is also known to be sensitive to alterations of sustained attention caused by common sleep disorders [19,20]. The PVT can quantify the level of sustained attention as well as the influence of state instability and time-on task effect [16,17,21,22]. According to the state instability theory, sleep deprivation leads to a fluctuation of sustained attention through the interaction of involuntary sleep initiating and counteracting wake-maintaining systems, and eventually increases the likelihood of lapses (failures in timely response, errors of omission) and false starts (errors of commission) [16,21]. The slope of response time in PVT measures indicates a time-on-task effect, which refers to the systematic deterioration in performance as a function of increasing task duration, and synonymously reflects the capability to maintain attention [16,22–24].

In the present study, the aim was to explore the impact of sleep duration and sleep-related complaints on sustained attention during the waking period at the population level. The PVT was adopted as a measure of sustained attention, which can be regarded as a surrogate marker of daytime functioning. To the best of the authors' knowledge, this is the first study to apply PVT and relate PVT performance to sleep indices in the general population. It was hypothesized that short sleep duration and sleep-related complaints would be related to psychomotor slowing, a higher level of state instability, and a lower level of capacity to maintain attention.

2. Methods

2.1. Study population

The present study is a sub-study to the "Korean Genome and Epidemiology Study" (KoGES), an on-going prospective community-based study, which was established in 2001 [25]. The original cohort consisted of 5020 (2523 males) adults, aged 40–69 years, from the Ansan province of South Korea. All information was collected by trained interviewers. Of specific relevance to the present study were subjects who participated in 2010–2011 ($N = 3144$; male 1600; mean age 57.3 ± 7.4 years). The PVT testing was performed in 3130 (99.6%; mean age 57.3 ± 7.4; male 1597, 51.0%) of 3144 participants. Because PVT performance is affected by sleep deprivation, the circadian phase and possibly by medical conditions, subjects with the following conditions were excluded: (1) shift workers ($N = 136$); (2) a history of stroke ($N = 82$), dementia ($N = 2$), psychiatric illness ($N = 26$), head trauma ($N = 9$), brain operation ($N = 19$), or cancer ($N = 54$); (3) any missing information relevant to this analysis ($N = 32$); (4) acute partial sleep deprivation on the night preceding the PVT test ($N = 335$). Acute partial sleep deprivation was defined as nocturnal sleep on the night before PVT testing that was shorter than habitual sleep duration by at least 1 h. While 2500 subjects qualified, one subject was additionally excluded, whose PVT responses were all errors (102 total stimuli with no valid response: nine false starts and 93 wrong keys). A total of 2499 participants (mean age 57.1 ± 7.3; male 1259) were included in the final analyses. The characteristics and PVT performances of the participants are presented in Table 1.

The institutional review board of the Korea University Ansan Hospital approved the study procedures, and written informed consent was obtained from all study participants.

Table 1
General characteristics and psychomotor vigilance task (PVT) performance.

Parameters	Values
Demographic factors and lifestyle	
Age (years)	57.1 ± 7.3
Male gender	1259 (50.4)
Right-handedness	2480 (99.2)
Current smoking	347 (13.9)
Current alcohol drinking	1327 (53.1)
Regular exercise[a]	1223 (48.9)
Education level	
<High school	790 (31.6)
≥High school	1709 (68.4)
Medical conditions and mood	
Overweight[a]	1086 (43.5)
Hypertension	839 (33.6)
Diabetes	496 (19.8)
Depressive mood[a]	357 (14.3)
Sleep-related factors	
ESS	5.3 ± 3.3
Subjective daytime sleepiness[a]	538 (21.5)
Reported sleep duration (h)	6.9 ± 1.2
<6	368 (14.7)
≥6 and <7	662 (26.5)
≥7 and <8	846 (33.9)
≥8 and <9	481 (19.2)
≥9	142 (5.7)
PSQI	4.6 ± 2.9
Poor sleep quality[a]	752 (30.1)
Habitual snoring[a]	475 (19.0)
Insomnia[a]	555 (22.2)
PVT performance	
Mean RRT (1/s)	3.76 ± 0.48
RRT slope (Δ1/s/min)	−0.031 ± 0.047
Lapses[b]	2.9 ± 5.9
<4	1941 (77.7)
≥4	558 (22.3)
False start[b]	2.2 ± 6.9
<3	1974 (79.0)
≥3	525 (21.0)
MST–PVT (h)	7.7 ± 1.5

Data presented as mean ± SD or number (%).
BMI refers to body mass index; ESS, Epworth Sleepiness Scale; MST-PVT, the interval between mid-sleep and PVT testing time; PSQI, Pittsburgh Sleep Quality index; PVT, psychomotor vigilance test; RRT, reciprocal response time.
[a] Each parameter defined as follows: regular physical exercise defined when subjects performed sweat-inducing exercise at least three times a week with each episode lasting at least 30 min; overweight as body mass index ≥25.0 kg/m^2; depressed mood as the Beck Depression Inventory score ≥16; subjective daytime sleepiness as the Epworth Sleepiness Scale score ≥8; poor sleep quality as the PSQI score >5; habitual snoring as subject reported snoring at least 4 nights a week; insomnia defined when subject had relevant symptoms at least 3 nights a week for more than a month.
[b] Lapses were defined as response time ≥500 ms; false starts as responses without a stimulus or response time <100 ms.

2.2. Measurements

2.2.1. Demographics, lifestyle, and health status

Demographic factors, including age and gender, were collected. Body mass index (kg/m^2) was calculated from height (cm) and body weight (kg) measured after overnight fasting. Overweight was a body mass index ≥25.0 [25]. Alcohol drinking and smoking status were categorized into two groups: current and never or former. Regular physical exercise was defined when subjects reported participating in sweat-inducing exercise at least three times a week for more than 30 mins for each activity. Education level was categorized into a low (<12-years of education) or high (≥12-years of education) group. Hypertension was diagnosed when systolic or diastolic blood pressure was ≥140 or 90 mmHg, respectively, or when participants took antihypertensive medications. Diabetes mellitus was considered to be present when there was use of oral hypoglycemic agent or insulin, or with fasting blood glucose ≥126 mg/dL