Impaired psychomotor vigilance associated with sleep-disordered breathing in female care workers for older adults in Japan

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Abstract

Purpose There is increasing interest in the health of female workers in the field of care services for older adults due to increasing demands to maintain 24-hour care and to support older adults without errors or accidents with a rapidly aging society. Therefore, the purpose of this cross-sectional study was to examine the association between sleep-disordered breathing (SDB) and sustained attention in female care workers for older adults in Japan.

Methods We conducted a study of 688 female workers aged 18–67 years old working in care service facilities for older adults in Japan. The sustained attention of participants was measured by the 10-minute psychomotor vigilance task (PVT). SDB was assessed based on the respiratory disturbance index (RDI), which was measured using an ambulatory airflow monitor with a polyvinylidene fluoride (PVDF) film sensor to monitor the respiratory airflow of nasal and oral breathing. The participants wore the monitor to record the breathing status while asleep at home. The severity of SDB was categorized as follows: normal, RDI <5 events/hour; mild SDB, RDI 5–10 events/hour; and moderate-to-severe SDB, RDI ≥10 events/hour.

Results The medians of age, body mass index (BMI), sleep duration, and prevalence of hypertension tended to be higher with increasing RDI. No significant association was found between RDI and PVT parameters. However, when we limited the analysis to women with BMI ≥22 kg/m^2, those with moderate-to-severe SDB had significantly higher odds of having the slowest 10% reaction times compared to those without SDB (OR = 2.03; 95% CI = 1.17–3.53). The association did not decrease after adjusting to account for sleep duration, alcohol drinking habits, and history of hypertension (OR =

1.97; 95% CI = 1.10–3.52). A significant increasing trend was also found between RDI and the slowest 10% of reaction times (*p* for trend = 0.03).

Conclusions Our findings suggest that SDB is associated with reduced sustained attention in participants with BMI ≥22 kg/m^2, although the number of assessments of SDB and PVT was only once per participant due to the nature of the cross-sectional study.

Key words: body mass index, psychomotor vigilance task, sleep disordered breathing, sustained attention.

Introduction

Sleep-disordered breathing (SDB) is a chronic morbid condition evidenced by repeated pauses in breathing during the sleep cycle, resulting in sleep fragmentation. SDB is one of the primary causes of adverse health conditions, including increased blood pressure, greater risk of cardiovascular and cerebrovascular diseases, neurocognitive dysfunction, impaired vigilance, and excessive daytime sleepiness [1, 2]. A study using polysomnographic recording techniques showed a prevalence of moderate-to-severe SDB (≥15 events per hour) in 23.4% of women and 49.7% of men in the general population [3]. Obstructive sleep apnea (OSA), the most common form of SDB, is defined as a decrease or complete cessation in airflow in the presence of breathing effort [4]. A systematic review of various studies worldwide has shown that the overall prevalence of OSA in the general population ranges from 9% to 38% with >5 events/h according to the apnea-hypopnea index (AHI) [5]. Considered together, excessive daytime sleepiness associated with OSA has been shown to reduce attention [6-8], resulting in an increased risk of motor vehicle accidents [9] or serious work-related accidents [10].

A 2019 nationwide survey on the working conditions of caregivers for older adults in Japan emphasized the overwhelming reliance on the female workforce (71.2%) for care services for older adults throughout the country [11]. The majority of such caregivers in existing facilities work in shifts around the clock to provide 24-hour support services to residents, despite the recognized adverse health implications of such a work schedule [12]. Furthermore, owing to the persistent traditional conventional wisdom in Japan that strongly suggests that women should stay home to perform household chores, female Japanese workers are overburdened by having multiple roles as both workers and as caregivers for their families [13, 14]. Indeed, previous studies have observed various mental health deficiencies and work-life imbalances in female Japanese workers [15-17]. A 2019 nationwide survey revealed that women who work in the sector of care services for older adults had the following complaints: physical burden (29.5%), mental burden (25.6%), night-time anxiety (17.1%), irregular work shifts (11.3%), and health risk anxieties, especially regarding infection and injury (11.2%) [11].

Studies of SDB in female workers worldwide have been limited. One study conducted in the 1990s found the prevalence of SDB (defined as an AHI ≥15, determined by overnight polysomnography (PSG)) in female workers in the United States to be 4.0% [18]. A general population-based study conducted in Switzerland reported a prevalence of SDB with AHI ≥5 and AHI ≥15 for 60.8% and 23.4%, respectively, in women 40 years of age and older [3]. In our previous study, we determined SDB using the respiratory disturbance index (RDI), which is defined as the number of events of breathing disturbances per hour while asleep. The prevalence of no SDB (RDI <5), mild SDB (5≤ RDI <10), and moderate-to-severe SDB (RDI ≥10) was 39.2%, 38.1%, and 22.8%, respectively [19], indicating that female workers in the care services sector for older adults in Japan are significantly impacted by SDB.

There is a growing demand within the labor force in the field of care services for older adults in Japan due to the rapidly aging population. Proper health management for workers in this sector is crucial for maintaining 24-hour care and support for older adults without errors or accidents. Previous studies have reported that night shift workers, including healthcare workers, tended to show deterioration in cognitive performance (e.g., deficits in alertness and sustained attention) caused by poor sleep-related issues [20-22]. Thus, the aim of the present study was to contribute to the understanding required for the realization of proper healthcare management by confirming the association between SDB and sustained attention in women working in this field.

Methods

Participants

In this study, female workers in care service facilities for older adults in Japan were selected between 2014 and 2016, irrespective of their status (type of job or working patterns); however, those who were diagnosed with SDB or treated for SDB were excluded. In total, 745 female participants were recruited, 17 of whom declined or were unable to participate due to work scheduling conflicts or sickness, 16 of whom failed to monitor their SDB while sleeping, and 24 of whom had missing data. The final group used for study analysis consisted of 688 participants aged 18–67 years old.

Outcome measurements

SDB was assessed based on RDI, which is defined as the number of events of breathing disturbances per hour while asleep. RDI was measured using a single-channel airflow monitor (NGK Spark Plug, Nagoya, Japan) with a PVDF film sensor, which monitors the respiratory airflow of nasal and oral breathing. The participants wore the monitor to record breathing status while asleep at home. The number of RDIs measured was one per participant. Recorded data were processed by a dedicated application program to calculate the RDI (at the Institute of Sleep Health Promotion, Tokyo, Japan). The measuring procedure was validated as being comparable to AHI measured based on polysomnography [23] and has been utilized in earlier studies [24, 25]. In short, RDI 5.3, RDI 11.4, and RDI 19.6 obtained based on this method were equivalent to AHI 5, AHI 15, and AHI 30, respectively. The previous validation study examined the reproducibility of the assessment of RDI using a single-channel airflow monitor, which was used in the present study. Nakano et al. reported that the reproducibility of the two results measured at home and the interclass correlation coefficient over two consecutive nights was 0.92, and the sensitivity of using an RDI of 11.4 to detect AHI 15 was 0.91, while the specificity was 0.82 [23]. In light of the small number of severe SDB cases (RDI ≥20, n = 27) in the present study, the participants were divided into the following categories: no SDB (RDI <5), mild SDB (RDI 5-10), and moderate-to-severe SDB (RDI ≥10).

Psychomotor vigilance task (PVT)

We used a PVT as a tool for the objective measurement of neurocognitive function. It is a simple test to record reaction time, in which participants are instructed to respond by pressing a button when visual stimuli appear at varying intervals ranging from 2 to 10 seconds. The test was conducted using a PVT-192 hand-held portable device (manufactured by CWE, Inc., Ardmore, PA, USA). The PVT assessment was performed anytime between 8:30 and 17:00 during working hours according to the participants' work schedules. The data utilized in this study were collected using a standard 10-minute method [26], according to which the participants were first given a 1-minute practice session, followed by the actual test (lasting 10 minutes). All reaction times (RTs) were recorded with the PVT device, and data were retrieved and analyzed by the dedicated software (PVTCOMMW and REACT), provided by the manufacturer. A reaction time greater than or equal to the median of the mean slowest 10% reaction time (392 milliseconds), considered the "high" slowest 10% reaction time, was used for the logistic regression analysis in the present study.

Covariates

Height (cm) and body weight (kg) were measured with light fabric and footwear off. Body mass index (BMI) was calculated as the body wight (kg) divided by the squared height (m). Blood pressure was continuously measured twice on the right arm with a 5-

minute interval between successive measurements, and the mean of the two readings was used for analysis. Hypertension was defined as a systolic blood pressure ≥140 mmHg, a diastolic blood pressure ≥90 mmHg, or the status of treatment with antihypertensive drugs. A self-completed questionnaire was used to collect data concerning age, the presence or absence of snoring, current alcohol consumption habits, current smoking habits, type of job, the presence or absence of shift work, onset of menopause, medical history, and scores for the Japanese version of the Epworth Sleepiness Scale (JESS) [27], Japanese version of the Athens Insomnia Scale (AIS-J) [28], the Perceived Stress Scale (PSS-4) [29], and the Center for Epidemiologic Studies Depression scale (CES-D) [30]. Insomnia was assessed based on the total score cutoff value for identifying the pathological condition of insomnia in the original AIS version and was determined to be 6 or more points [31].

Data and statistical analyses

The Shapiro-Wilk test was used to assess the normality of the data. The Jonckheere-Terpstra trend test was then applied to assess trends in continuous variables, while the Cochran-Armitage trend test was used to assess binary variable trends. Data are presented as the means and standard errors or medians and interquartile ranges (IQRs). Multivariate logistic regression analyses were used to assess the independent association between PVT parameters and SDB severity by RDI categories. To assess the potential modifying effects of age and BMI on the associations, we ran regression models stratified by median age (age <39 or ≥39) and BMI (BMI <22 or ≥22 kg/m^2).

All of the statistical analyses were performed with EZR (at the Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (developed by the R Foundation for Statistical Computing, Vienna, Austria). EZR is a modified version of the R Commander designed to add statistical methodologies frequently used in biostatistics and improve operability [32].

Results

The basic characteristics of the participants according to SDB categories are presented in Table 1. Overall, the median age was 38 years old (IQR = 27–48 years), and the median BMI was 22.0 kg/m^2 (IQR = 20.2–24.8 kg/m^2). The prevalence of normal, mild SDB, and moderate-to-severe SDB was 39.5% (n = 272), 37.5% (n = 258), and 22.9% (n = 158), respectively. Female workers with moderate-to-severe SDB were older and tended to have a higher BMI, history of hypertension, and shorter sleep durations. However, self-rated scales for evaluating daytime sleepiness (Japanese version of the Epworth sleepiness scale, JESS), insomnia (Japanese version of the Athens insomnia scale, AIS-J), and being a shift worker were not correlated with the severity of SDB in this study.

Table 2 shows the PVT performance parameters according to SDB categories, revealing that there were no significant differences in any of the parameters. A trend for increases in the mean of the slowest 10% of RT was observed, in line with the increases in RDI; however, this observation was not statistically significant ($p = 0.15$).

We further investigated the impact of age and BMI on the association between PVT performance and SDB by stratified analyses of age and BMI. Table 3 shows the results from the analysis stratified by age group (age <39 or ≥39), from which it is evident that no trends for prolonged RT or increases in any PVT parameters were observed. Table 4 presents the analysis stratified by BMI category (BMI <22 or ≥22 kg/m^2), revealing a significant trend in the increase of the mean of the slowest 10% of RT in participants with BMI ≥22 kg/m^2, observed in line with the increase of in RDI (p for trend = 0.03).

Moreover, Table 5 shows the odds ratios (ORs) for the higher mean of the slowest 10% of RT in accordance with the RDI categories. Among participants with BMI

≥22kg/m^2, there were significant odds of having a higher mean of the slowest 10% of RT for those with moderate-to-severe SDB compared to those without SDB (OR = 2.03; 95% confidence interval (CI) = 1.17–3.53). The association was not attenuated after adjustments were made to account for sleep duration, alcohol drinking habits, and history of hypertension (OR = 1.97; 95% CI = 1.10–3.52).

Discussion

This study is the first to examine the association between SDB and impaired vigilance in relatively young female Japanese workers in care service facilities for older adults. A significant increasing trend was observed for the mean duration of the slowest 10% of reaction times, as RDI increased in participants with BMI ≥22 kg/m^2.

Deterioration of PVT performance in participants with a high BMI has been reported in previous studies [6, 33-36]. The majority of these studies examined male subjects with a mean BMI ranging from 26.54 to 31.3 kg/m^2, which is much higher than that in our study. Another study examined PVT performance in relatively young female shift workers (median age 34 years; IQR = 28–47 years) in a German hospital [22]. However, their average BMI was also higher than that in our study population (i.e., median BMI = 24.8 kg/m^2 (IQR = 22.8–29.2 kg/m^2) vs. 22.0 kg/m^2 (IQR = 20.2–24.8 kg/m^2)) [22]. Thus, the BMI of our study subjects was much lower than that in previous studies conducted in Western countries, and the difference in BMIs between the studies might be one of the primary reasons why there were no significant associations between SDB and PVT performance in the present study. When we limited the analysis to the subset of participants with BMIs ≥22 kg/m^2, we found a significant association between SDB and the mean of the slowest 10% of reaction times, a measure that has been recognized as reflecting deterioration of vigilance and sustained attention [26, 37-39]. Our results and those of previous findings suggest that worsening SDB impairs vigilance and affects sustained attention in participants with BMI ≥22 kg/m^2.

The association between impaired PVT performance and OSA in obese subjects has been reported in previous studies [33, 36]. Two fundamental aspects of OSA are sleep fragmentation [40-43] and intermittent hypoxia [44-47], both of which adversely affect the prefrontal cortex and its interaction with the thalamus. Adverse effects on the thalamus have subsequently been associated with decreases in alertness, vigilance, and selective and sustained attention [48, 49]. Moreover, OSA-induced sleep deprivation has been shown to be a potential contributing factor to body weight gain due to overeating [50]. It was reported that obese individuals have decreased regional cerebral blood flow in prefrontal brain regions associated with attention, reasoning, and executive function [51]. Therefore, being overweight/obese can exacerbate the adverse association between SDB and sustained attention in the present study.

One of the strengths of this study is the inclusion of relatively young female subjects with low BMIs. Subjects in many previous studies on the association between SDB or OSA and PVT variables consisted of OSA-diagnosed patients [6, 33, 52-54], middle-aged to older community-dwelling adults [6, 35], or male commercial drivers [36]. Furthermore, using RDI is appropriate for the assessment of SDB in subjects with low BMIs. Assessments of SDB based on the oxygen desaturation index (ODI) have been shown to be susceptible to body habitus and, more specifically, the correlation between the ODI and AHI since the ODI is lower in normal weight subjects than in overweight subjects [23]. Another strength of this study is that the participants' respiratory state during sleep was recorded in their homes. Data collection was performed in a typical setting for the participant, no different from any other day (e.g., familiar sleeping space, daily habits including alcohol consumption). Our data are therefore based on a more realistic setting than some of the preceding laboratory-based studies.

There are several limitations to the current study. First, as a cross-sectional study, it was unable to establish causality between SDB and the impairment of psychomotor function. Second, sleep duration during the data collection for the state of participants' respiration relied on self-reporting by participants. We might need to consider the imprecision inherent in calculating RDI due to a lack of objectivity in reporting sleep duration. Third, the PVT assessment was performed anytime between 8:30 and 17:00 during working hours, according to the participants' work schedules. Circadian fluctuation could be an important factor affecting the assessment of PVT performance.

Despite the limitations, the results of our study suggest that reduced sustained attention occurs in relatively young women with both SDB and obesity. Due to the rapid increase in the aging population, there is growing demand for a labor force of women in the field of care services for older adults worldwide. Since a causal role of excess weight in SDB is evident [33, 55], the prevention and reduction of overweight and obesity could be crucial for the health management of care workers maintaining 24-hour care and support for older adults without errors or accidents.

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Author contributions

Study concept and design: NM, AI, HW, KM, YS, and TT. Acquisition of data: NM, AI, HW, KM, YS, RF, YS, SI, YH, and TT. Statistical analysis and drafting of the manuscript: NM. Analysis, interpretation of data, and critical revision of the manuscript for important intellectual content: all authors.

Compliance with ethical standards

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Conflict of interest Takeshi Tanigawa is a part-time occupational physician of Koyama Healthcare Group. The other authors declare no conflicts of interest.

Ethical approval This study was approved by the Ethical Review Board of the Juntendo University Faculty of Medicine in 2014 (authorization number: 2014057). All procedures performed in studies involving human participants were conducted in accordance with ethical standards and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in this study.

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Table titles and legends

Table 1 Basic characteristics of the study participants according to the severity of sleep-disordered breathing.

Results of continuous data are expressed as medians and interquartile ranges (IQRs), and the results of binary data are expressed as numbers (N) and percentages (%).

The Jonckheere-Terpstra trend test was applied to assess continuous variables (age, body mass index, sleep duration, Japanese version of Epworth Sleepiness Scale and Japanese version of the Athens Insomnia Scale), while the Cochran-Armitage trend test was applied to assess binary variables (insomnia, shift workers, nonshift workers, hypertension, alcohol drinking habit, and smoking habit).

SDB sleep-disordered breathing, *RDI* respiratory disturbance index, *BMI* body mass index, *JESS* Japanese version of Epworth sleepiness scale, *AIS-J* Japanese version of the Athens Insomnia Scale, *N* number

* $p<0.05$

Table 2 Psychomotor vigilance task performance according to sleep-disordered breathing categories.

Results of continuous data are expressed as medians and interquartile ranges (IQRs)

The Jonckheere-Terpstra trend test was applied to assess trends.

PVT psychomotor vigilance task, *SDB* sleep-disordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *ms* milliseconds

Table 3 Stratified analysis of psychomotor vigilance task performance according to sleep-disordered breathing categories by age.

Results of continuous data are expressed as medians and interquartile ranges (IQRs).

The Jonckheere-Terpstra trend test was applied to assess trends.

PVT psychomotor vigilance task, *SDB* sleep-disordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *ms* milliseconds

Table 4 Stratified analysis of psychomotor vigilance task performance according to sleep-disordered breathing by BMI.

Results of continuous data are expressed as medians and interquartile ranges (IQRs).

The Jonckheere-Terpstra trend test was applied to assess trends.

PVT psychomotor vigilance task, *SDB* sleep-disordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *ms* milliseconds

* $p<0.05$

Table 5 Odds ratios with 95% confidence intervals of high slowest 10% RT according to the SDB categories.

Model 1: no adjustment.

Model 2: adjusted by sleep duration, alcohol drink habit, and hypertension.

High mean of the slowest 10% RT indicated that the mean of the slowest 10% reaction time was greater than or equal to 392 milliseconds (ms).

SDB sleep-ordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *OR* odds ratio, *CI* confidential interval

* $p<0.05$

Table 1 Basic characteristics of the study participants according to the severity of sleep-disordered breathing.

	Total		SDB Categories						*p* for trend
			Normal		Mild		Moderate-to-severe		
	Total n = 688		RDI < 5 n = 272		RDI 5 - 10 n = 258		RDI ≥ 10 n = 158		
Age (years)	38	(27 - 48)	34	(25 - 43)	37	(28 - 47)	46.5	(38 - 53)	< 0.01*
BMI (kg/m^2)	22.0	(20.2 - 24.8)	21.6	(20.1 - 23.5)	22.0	(19.9 - 24.8)	23.4	(21.0 - 27.3)	< 0.01*
Sleep duration (hours)	6	(5 - 7)	6	(6 - 7)	6	(5 - 7)	6	(5 -7)	0.03*
JESS (score)	8	(5 - 11)	9	(5 - 12)	8	(5 - 11)	7	(5 - 10)	0.11
AIS-J (score)	4	(2 - 7)	4	(2 - 6)	4	(2 - 7)	4	(2 - 6)	0.77
Insomnia (N)	232	(33.7%)	81	(34.9%)	100	(43.1%)	51	(22.0%)	0.38
Shift workers (N)	244	(35.5%)	91	(37.3%)	100	(41.0%)	53	(21.7%)	0.83
Non-shift workers (N)	443	(64.5%)	180	(40.6%)	158	(35.7%)	105	(23.7%)	0.83
Hypertension (N)	76	(11.0%)	15	(5.5%)	26	(10.1%)	35	(22.2%)	< 0.01*
Alcohol drink habit (N)	253	(36.8%)	89	(32.7%)	94	(36.4%)	70	(44.3%)	0.02*
Smoking habit (N)	170	(24.7%)	63	(23.2%)	69	(26.7%)	38	(24.1%)	0.72

Results of continuous data are expressed as medians and interquartile ranges (IQRs), and the results of binary data are expressed as numbers (N) and percentages (%).

The Jonckheere-Terpstra trend test was applied to assess continuous variables (age, body mass index, sleep duration, Japanese version of Epworth Sleepiness Scale and Japanese version of the Athens Insomnia Scale), while the Cochran-Armitage trend test was applied to assess binary variables (insomnia, shift workers, nonshift workers, hypertension, alcohol drinking habit, and smoking habit).

SDB sleep-disordered breathing, *RDI* respiratory disturbance index, *BMI* body mass index, *JESS* Japanese version of Epworth sleepiness scale, *AIS-J* Japanese version of the Athens Insomnia Scale, *N* number

* $p<0.05$

Table 2 Psychomotor vigilance task performance according to sleep-disordered breathing categories.

PVT Variables			**SDB Categories**						
	Total		**Normal**		**Mild**		**Moderate-to-severe**		**p for trend**
			RDI < 5		**RDI 5 - 10**		**RDI ≥ 10**		
	n = 688		**n = 272**		**n = 258**		**n = 158**		
Median RT (ms)	250	(233 - 273)	254	(234 - 272)	249	(231 - 272)	250	(232 - 273)	0.88
Mean RT (ms)	267	(246 - 287)	268	(246 - 288)	264	(245 - 285)	269	(245 - 288)	0.86
Fastest 10% RT (ms)	200	(188 - 214)	201	(188 - 215)	198	(187 - 212)	201	(188 - 216)	0.74
Slowest 10% RT (ms)	392	(354 – 447)	388	(349 - 447)	389	(357 - 448)	403	(368 - 448)	0.15
Lapses (number)	1	(0 - 2)	1	(0 - 2)	1	(0 - 2)	1	(0 - 2)	0.36
False Start (number)	0	(0 - 1)	0	(0 - 1)	0	(0 - 1)	0	(0 - 1)	0.31

Results of continuous data are expressed as medians and interquartile ranges (IQRs)

The Jonckheere-Terpstra trend test was applied to assess trends.

PVT psychomotor vigilance task, *SDB* sleep-disordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *ms* milliseconds

Table 3 Stratified analysis of psychomotor vigilance task performance according to sleep-disordered breathing categories by age.

PVT Variables	**Total** n = 688	**SDB Categories** Normal RDI < 5 n = 272	Mild RDI 5 - 10 n = 258	Moderate-to-severe RDI ≥ 10 n = 158	***p* for trend**
Age <39	347	164	138	45	
Age ≥39	341	108	120	113	
Median RT (ms)	250 (233 - 273)	254 (234 - 272)	249 (231 - 272)	250 (232 - 273)	0.88
Age <39	248 (229 - 269)	251 (233 - 271)	247 (227 - 267)	245 (228 - 269)	0.28
Age ≥39	255 (236 - 276)	255 (236 - 276)	256 (239 - 278)	254 (236 - 274)	0.65
Mean RT (ms)	267 (246 - 287)	268 (246 - 288)	264 (245 - 285)	269 (245 - 288)	0.86
Age <39	262 (240 – 284)	265 (243 - 286)	260 (240 - 279)	257 (235 - 288)	0.44
Age ≥39	271 (251 - 291)	272 (252 - 295)	270 (251 - 292)	271 (251 - 287)	0.74
Fastest 10% RT (ms)	200 (188 - 214)	201 (188 - 215)	198 (187 - 212)	201 (188 - 216)	0.74
Age <39	198 (184 - 212)	199 (186 - 215)	197 (185 - 207)	198 (177 - 210)	0.21
Age ≥39	202 (191 - 215)	204 (193 - 215)	200 (190 - 214)	202 (192 - 218)	0.71
Slowest 10% RT (ms)	392 (354 – 447)	388 (349 - 447)	389 (357 - 448)	403 (368 - 448)	0.15
Age <39	381 (345 - 440)	375 (344 - 444)	381 (342 - 430)	399 (349 - 543)	0.59
Age ≥39	409 (366 - 452)	413 (362 - 447)	402 (369 - 464)	410 (363 - 449)	0.93
Lapses (number)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0.36
Age <39	0 (0 - 1.5)	0 (0 - 2)	0 (0 - 1)	1 (0 - 2)	0.49
Age ≥39	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0.94
False Start (number)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.31
Age <39	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.46
Age ≥39	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.54

Results of continuous data are expressed as medians and interquartile ranges (IQRs).

The Jonckheere-Terpstra trend test was applied to assess trends.

PVT psychomotor vigilance task, *SDB* sleep-disordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *ms* milliseconds

Table 4 Stratified analysis of psychomotor vigilance task performance according to sleep-disordered breathing by BMI.

PVT Variables		SDB Categories			
	Total n = 688	Normal RDI < 5 n = 272	Mild RDI 5 - 10 n = 258	Moderate-to-severe RDI ≥ 10 n = 158	*p* for trend
BMI <22 kg/m^2	345	156	128	61	
BMI ≥22 kg/m^2	343	116	130	97	
Median RT (ms)	250 (233 - 273)	254 (234 - 272)	249 (231 - 272)	250 (232 - 273)	0.88
BMI <22 kg/m^2	248 (231 - 269)	250 (233 - 271)	248 (226 - 268)	245 (227 - 267)	0.13
BMI ≥22 kg/m^2	255 (236 - 276)	256 (235 - 275)	253 (237 - 275)	259 (238 - 276)	0.52
Mean RT (ms)	267 (246 - 287)	268 (246 - 288)	264 (245 - 285)	269 (245 - 288)	0.86
BMI <22 kg/m^2	263 (242 - 282)	265 (246 - 287)	261 (243 - 281)	255 (236 - 280)	0.10
BMI ≥22 kg/m^2	269 (249 - 292)	270 (247 - 289)	266 (249 - 291)	272 (253 - 298)	0.19
Fastest 10% RT (ms)	200 (188 - 214)	201 (188 - 215)	198 (187 - 212)	201 (188 - 216)	0.74
BMI <22 kg/m^2	198 (185 - 212)	200 (186 - 214)	196 (186 - 211)	196 (178 - 209)	0.20
BMI ≥22 kg/m^2	202 (191 - 214)	204 (193 - 215)	201 (188 - 213)	203 (192 - 219)	0.75
Slowest 10% RT (ms)	392 (354 – 447)	388 (349 - 447)	389 (357 - 448)	403 (368 - 448)	0.15
BMI <22 kg/m^2	387 (353 - 437)	386 (349 - 448)	387 (357 - 437)	387 (352 - 423)	0.61
BMI ≥22 kg/m^2	397 (356 - 453)	389 (349 - 447)	394 (358 - 456)	413 (371 - 457)	0.03*
Lapses (number)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0.36
BMI <22 kg/m^2	1 (0 - 1)	1 (0 - 2)	1 (0 - 1)	1 (0 - 1)	0.82
BMI ≥22 kg/m^2	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0.25
False Start (number)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.31
BMI <22 kg/m^2	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.02
BMI ≥22 kg/m^2	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0 (0 - 1)	0.41

Results of continuous data are expressed as medians and interquartile ranges (IQRs).

The Jonckheere-Terpstra trend test was applied to assess trends.

PVT psychomotor vigilance task, *SDB* sleep-disordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *ms* milliseconds

* $p<0.05$

Table 5 Odds ratios with 95% confidence intervals of high slowest 10% RT according to the SDB categories.

	SDB Categories						
	Normal RDI <5	**Mild RDI 5 - 10**			**Moderate-to-severe RDI ≥10**		
High Mean of the Slowest 10% RT		**OR**	**95% CI**	***p*-value**	**OR**	**95% CI**	***p*-value**
BMI <22 kg/m²							
No. of cases	156	128			61		
Model 1	1.00	0.90	(0.56 - 1.43)	0.64	0.92	(0.51 - 1.66)	0.77
Model 2	1.00	0.90	(0.56 - 1.44)	0.66	0.92	(0.50 - 1.67)	0.78
BMI ≥22 kg/m²							
No. of cases	116	130			97		
Model 1	1.00	1.22	(0.74 - 2.02)	0.44	2.03	(1.17 - 3.53)	0.01*
Model 2	1.00	1.20	(0.72 - 2.00)	0.50	1.97	(1.10 - 3.52)	0.02*

Model 1: no adjustment.

Model 2: adjusted by sleep duration, alcohol drink habit, and hypertension.

High mean of the slowest 10% RT indicated that the mean of the slowest 10% reaction time was the greater than or equal to 392 milliseconds (ms).

SDB sleep-ordered breathing, *RDI* respiratory disturbance index, *RT* reaction time, *OR* odds ratio, *CI* confidential interval

* $p<0.05$