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Current Alzheimer Research, 2022, *19*, 954-964

CROSS SECTIONAL STUDY

Sleep Characteristics in Older Adults with Different Levels of Risk for Dementia: A Cross-sectional Study

Xiuxiu Huang[1], Shifang Zhang[1], Yuxi Fang[1], Xiaoyan Zhao[1], Ting Cao[1], Yongan Sun[2,*] and Qiaoqin Wan[1,*]

[1]*School of Nursing, Peking University, 38 Xueyuan Road, Haidian District, Beijing, 100191, China;* [2]*Department of Neurology, Peking University First Hospital, 8 Xishiku Street, Xicheng District, Beijing, 100034, China*

ARTICLE HISTORY

Received: November 14, 2022
Revised: February 08, 2023
Accepted: February 18, 2023

DOI:
10.2174/1567205020666230303110244

Abstract: ***Background*:** Sleep problems are very prevalent in older adults, especially in those at risk for dementia. But the relationships between sleep parameters and subjective or objective cognitive decline are still inconclusive.

***Aim*:** The study aimed to investigate the self-reported and objectively measured sleep characteristics in older adults with mild cognitive impairment (MCI) and subjective cognitive decline (SCD).

***Methods*:** This study adopted a cross-sectional design. We included older adults with SCD or MCI. Sleep quality was measured separately by the Pittsburgh sleep quality index (PSQI) and ActiGraph. Participants with SCD were divided into low, moderate, and high levels of SCD groups. Independent samples T-tests, one-way ANOVA, or nonparametric tests were used to compare the sleep parameters across groups. Covariance analyses were also performed to control the covariates.

***Results*:** Around half of the participants (45.9%) reported poor sleep quality (PSQI $<$ 7), and 71.3% of participants slept less than 7 hours per night, as measured by ActiGraph. Participants with MCI showed shorter time in bed (TIB) ($p < 0.05$), a tendency of shorter total sleep time (TST) at night ($p = 0.074$) and for each 24-hour cycle ($p = 0.069$), compared to those with SCD. The high SCD group reported the highest PSQI total score and longest sleep latency than all the other three groups ($p < 0.05$). Both the MCI and high SCD groups had shorter TIB and TST for each 24-hour cycle than the low or moderate SCD groups. Besides, participants with multiple-domain SCD reported poorer sleep quality than those with single-domain SCD ($p < 0.05$).

***Conclusion*:** Sleep dysregulation is prevalent in older adults with a risk for dementia. Our findings revealed that objectively measured sleep duration might be an early sign of MCI. Individuals with high levels of SCD demonstrated poorer self-perceived sleep quality and deserved more attention. Improving sleep quality might be a potential target to prevent cognitive decline for people with a risk for dementia.

Keywords: Sleep, cognition, aged, subjective cognitive decline, mild cognitive impairment, dementia.

1. INTRODUCTION

Cognitive impairment has become a leading cause of disability in older adults worldwide, imposing a heavy burden on patients themselves, family caregivers, and the public health systems [1]. Considering the current status of dementia treatments, early identification and prevention are very essential. Mild cognitive impairment (MCI) is the transitional stage between normal cognition and dementia, and is taken as the prodromal stage of Alzheimer's dementia. It was estimated that the overall prevalence of MCI was 15.5% in Chinese adults aged 60 years or older, representing 38.77 million individuals with MCI [2]. Subjective cognitive decline (SCD) was conceived in 2014 by the international working group of the SCD Initiative to describe this condition as a self-experienced persistent decline in cognitive capacity, but there was no evidence of objective cognitive impairment [3]. Population-based studies reveal that around 50% ~ 80% of individuals aged 70 and above report self-perceived cognitive decline, including executive function, memory, and visuospatial function [4, 5]. Longitudinal studies suggest people with SCD and MCI to have a higher risk of progression to dementia [6, 7]. It is acknowledged that SCD and MCI are the two critical stages for the prevention of dementia. Hence, it means a lot to early identify and manage the modifiable risk factors, which may accelerate the progress of cognitive decline in people with MCI and SCD.

*Address correspondence to these authors at the Department of Neurology, Peking University First Hospital, 8 Xishiku Street, Xicheng District, Beijing, 100034, China; E-mail: sya@bjmu.edu.cn (Y.S.); School of Nursing, Peking University, 38 Xueyuan Road, Haidian District, Beijing, 100191, China; E-mail: qqwan05@163.com (Q.W.)

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Current Alzheimer Research

Sleep problems are very prevalent in older adults as a frequently-mentioned risk factor of cognitive decline, especially in the era of COVID-19 [8]. The relationship between sleep and cognition has attracted much attention from researchers. However, the relationship between sleep parameters and subjective or objective cognitive decline is still inconclusive.

Previous studies have implied that there might exist a bidirectional relationship between sleep disturbance and cognitive impairment [9, 10]. On one side, sleep disturbances could accelerate objective cognitive decline by inducing microglial dysfunction and neuroinflammation, increasing amyloid-β (Aβ) accumulation, decreasing Aβ clearance, and affecting neuronal plasticity [10-12]. On the other side, cognitive impairment also leads to alterations in sleep architecture by interfering with the normal functions of brain regions associated with sleep control due to the amyloid plaques [10, 13]. The lifestyle changes accompanied by cognitive declines, such as less physical activity and less exposure to daylight, also have negative influences on sleep quality [10]. In another word, there may exist a positive feedback loop between sleep dysfunction and cognitive impairment. Therefore, a deep understanding of the sleep characteristics in people at risk for dementia is helpful to take corresponding measures to break the vicious circle and prevent the development of cognitive impairment.

As for the sleep parameters in people with MCI, different studies have reported various characteristics although most of the studies have acknowledged that people with MCI generally suffer from poorer sleep. Rozzini *et al.* found individuals with MCI to have higher frequencies of daytime dysfunction and sleep medication use compared to healthy elderly volunteers [9]. Zhang *et al.* revealed shorter or longer sleep duration to be an important factor independently related to MCI [14]. Palmer *et al.* reported individuals with MCI to suffer more awakenings during the night compared to cognitively healthy controls [15]. The inconsistencies in sleep characteristics reported in previous studies were probably caused by the heterogeneity of measurement tools for self-reported sleep quality. Furthermore, most previous studies have investigated the self-reported sleep quality in MCI individuals with cognitively healthy volunteers as controls. Nevertheless, it is not clear whether there exist differences in self-reported or objectively measured sleep quality between individuals with MCI and SCD, at different levels of risk for dementia.

In contrast, the sleep characteristics in older adults with SCD are less known, especially in Chinese older adults. The limited research shows inconsistent results with respect to the relationship between sleep parameters (*i.e.,* sleep duration, sleep latency, and sleep efficiency) and SCD [16-18]. On one hand, it may be probably caused by the differences in the measurement methods of sleep quality (mostly self-reported) and SCD. On the other hand, SCD is a potentially overinclusive condition and there exist inevitable differences among older adults with different levels of subjective cognitive complaints [3], which directly lead to inconsistencies across previous studies. However, to our knowledge, no studies have explored the sleep characteristics in older adults with different levels of cognitive complaints so far, especially the objectively measured sleep characteristics. There is also a lack of evidence about the comparisons of sleep quality between older adults with SCD and MCI. It is not clear which sleep parameters are associated with subjective cognitive decline and which are related to objective cognitive impairment.

Therefore, this study aimed to investigate the sleep-related characteristics, through both subjective and objective approaches, in older adults with MCI and different severities of SCD, and to reveal the relationship between self-reported or objectively measured sleep parameters and subjective or objective cognitive decline.

2. MATERIALS AND METHODS

2.1. Design

The study adopted a cross-sectional design. We have reported our findings as per the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (Supplementary file **1**).

2.2. Participants

Participants were recruited from primary health service centers and memory clinics in Beijing from November 2020 to November 2021. The inclusion criteria for participants were as follows: (a) aged 60 and above; (b) reporting a subjective cognitive decline (the score of Montreal Cognitive Assessment or diagnosed with MCI according to Peterson criteria; (c) dwelling in the community; (d) willing to participate in this study. Participants were excluded if they scored lower than 24 points on the Mini-Mental State Examination (MMSE) or had major depression, which was evaluated by the Patient Health Questionnaire-9 (PHQ-9). A cutoff score ≥ 11 was used to detect major depression [19]. Besides, we excluded the participants who had not retired from their professional careers. Sample size was calculated using PASS 11 according to the results of a study by Leng *et al.* [20], with a significance level of 0.05 and a power of 0.99. The minimum sample size for the study was 164 participants (n_{SCD}=123, n_{MCI}=41). Given an invalid response rate of 20%, we planned to collect data from at least 205 participants.

2.3. Ethical Approval

This cross-sectional study has been approved by the Institutional Review Board (Approval Number: IRB00001052-21166). All procedures involving the participants were in accordance with the Declaration of Helsinki. Oral informed consent was obtained from all participants before data collection in our study.

2.4. Data Collection

Subsequently to the approval of the ethics committee, the survey was conducted in Beijing from November 2020 to November 2021. All the investigators undertook unified training before the investigation. The following data were collected after the obtainment of an informed consent.

2.4.1. Global Cognition

Global cognition was evaluated by the Montreal Cognitive Assessment (MoCA), which was reported to be the best

test for the detection of MCI [21]. The population-based study in Chinese elderly individuals showed that the optimal cutoff points of MoCA for detecting MCI were 24/25 for individuals with 7 or more years of education, 19/20 for individuals with 1 to 6 years of education, and 13/14 for illiterate individuals [22].

2.4.2. Subjective Cognitive Decline

Subjective cognitive decline was measured by the structural and combined questionnaire on subjective cognitive complaints. The questionnaire involved five cognitive domains: memory, executive function, attention, naming, and orientation. The section on memory complaints consisted of nine items, with a score ranging from 0 to 7.5, which were developed by Gifford *et al.* [23] and translated by Chinese researchers [24]. In addition, we added five more items to evaluate participants' complaints on executive function (2 items), attention (1 item), naming (1 item), and orientation (1 item) according to previous studies [25]. Each item was scored 0 (no) or 1 (yes) except three items in the memory section, which were scored by three-grade (0 = never, 0.5 = sometimes, 1 = always). Participants with only memory complaints were classified as the single-domain SCD group and those with other cognitive complaints besides memory were defined as the multiple-domain SCD group.

2.4.3. Sleep Quality

Self-reported sleep quality in the past month was measured by the Chinese version of the Pittsburg Sleep Quality Index (PSQI) with 19 items [26]. The PSQI consists of seven dimensions (subjective sleep quality, sleep duration, sleep latency, sleep efficiency, sleep disturbances, sleep medications, and daytime dysfunction) and each of them has a possible score of 0 to 3. The total score of PSQI ranges from 0 to 21. Higher scores reflect poorer sleep quality, with a score of 7 as the cut-off score distinguishing good ($\geq$7) and poor sleep ($<$7) [27]. The Chinese version of PSQI has been used in many epidemiological studies with good reliability and validity [26, 27].

Objective sleep quality was measured by ActiGraph wGT3X-BT (ActiGraph, LLC. Pensacola, FL, USA), a wrist-worn accelerometer. It assesses sleep or waking state by measuring wrist movements. Wrist actigraphy has been proven to be a highly accurate tool for measuring sleep when compared to polysomnography [28]. Participants were guided to wear the actigraphy on their non-dominant hands for a week and complete the sleep diary. The raw data from the actigraphy were processed within 48 hours using the software of ActiLife (ActiGraph, LLC. Pensacola, FL, USA) through Cole-Kripke algorithms, and the exported sleep reports were returned to the participants in time for double check. The first 10 minutes of non-activity periods were taken as sleep onset and the end of the last 10 minutes of non-activity periods was judged as sleep end [29]. The following sleep parameters were extracted for analysis: time in bed (TIB), total sleep time (TST) at night, sleep efficiency, wake after sleep onset (WASO), number of awakenings, average awakening time, and TST in the daytime.

2.4.4. Covariates

Since age and gender might influence sleep quality, we included them as covariates. Participants' medical conditions were also assessed through the self-administered comorbidity questionnaire (SACQ) with scores ranging from 0 to 45 [30]. An individual can receive a maximum of 3 points for each medical condition: 1 point for the presence of the medical problem, another point for the received corresponding treatment, and an additional point if the medical problem causes a functional limitation.

2.5. Statistical Analysis

Participants were divided into the SCD group and the MCI group. Then, the SCD group was further divided into three groups (low SCD, moderate SCD, and high SCD group) according to the tertiles of the total score of the questionnaire related to subjective cognitive complaints, since there are no established thresholds for the degree of SCD. Categorical variables were described by counts and constituent ratios. For continuing variables, means and standard deviations were used for descriptive analysis.

We first performed an independent T-test for the comparison of sleep parameters between the whole SCD group and the MCI group. Then, one-way ANOVA was adopted for the comparative analysis of normal data and transformed normal data. To test the reliability of one-way ANOVA results, we also adopted covariance analyses. Model 1 included age and gender as covariates. Model 2 additionally added the SACQ score as a covariate. We used the LSD test for post-hoc multiple comparisons. For the non-normal data, which could not be transformed into normal data, we used the Kruskal-Wallis H-test to compare the differences across four groups, and multicomponent comparisons were performed using Dunn's test. Additionally, we also examined the sleep quality differences between the single-domain SCD group and the multiple-domain SCD group using the independent samples T-test or Mann-Whitney U test. All the statistical analyses were conducted through SPSS 23, and PRISM graph 9.0 software was used for plotting.

3. RESULTS

3.1. Sample Characteristics

A total of 207 eligible participants were included in the analysis, with 30.4% of men and 69.6% of women. The eligible ActiGraph data were collected from 94 participants out of 207 eligible participants. 73 participants were in the MCI group with a mean age of 72.9 (SD = 7.7), and 134 participants with SCD were divided into the low SCD group (n = 42), moderate SCD group (n = 50), and high SCD group (n = 42) according to the tertiles of the SCD questionnaire scores. The details are provided in Table **1**.

3.2. The Quality of Sleep

The average PSQI score was 6.69 (SD = 4.51). About half of the participants (45.9%) reported poor sleep quality with a PSQI score lower than 7, and the high SCD group had the highest proportion (67.5%) of bad sleepers. Fig. (**1**) shows the scores' distribution for each subscale of PSQI. There were the highest percentages of participants in the high SCD group who reported higher scores (2 or 3) for each subscale except for the subscale sleep disturbances. The average TST at night measured by ActiGraph was 6.52 (SD =

Table 1. Participants' characteristics.

-	SCD (n=134)			MCI (n=73)
	Low SCD (n=42)	Moderate SCD (n=50)	High SCD (n=42)	
Age, mean (SD)	71.92 (7.33)	71.09 (6.83)	70.02 (6.34)	72.88 (7.72)
Gender, n (%)	-	-	-	-
Male	15 (23.8%)	18 (28.6%)	9 (14.3%)	21 (33.3%)
Female	27 (18.8%)	32 (22.2%)	33 (22.9%)	52 (36.1%)
Education, n (%)	-	-	-	-
High school and below	16 (39.0%)	19 (39.6%)	21 (50%)	42 (61.76%)
College level	11 (26.8%)	13 (27.1%)	14 (33.3%)	11 (16.2%)
Bachelor and above	14 (34.1%)	16 (33.1%)	7 (16.7%)	15 (22.1%)
MoCA score, mean (SD)	26.60 (1.17)	27.10 (1.54)	26.46 (1.40)	21.75 (3.02)
SACQ score, mean (SD)	3.63 (2.62)	3.94 (2.75)	4.97 (3.05)	4.98 (3.34)
PSQI score, n (%)	-	-	-	-
Good sleep (PSQI＜7)	23 (57.5%)	33 (68.8%)	13 (32.5%)	37 (54.4%)
Poor sleep (PSQI≥7)	17 (42.5%)	15 (31.3%)	27 (67.5%)	31 (45.6%)

Abbreviations: SCD: subjective cognitive decline; MCI: mild cognitive impairment; SD: standard deviation; MoCA: the Montreal Cognitive Assessment; SACQ: the self-administered comorbidity questionnaire; PSQI: the Pittsburgh sleep quality index.

0.96), and more than two-thirds of participants (71.3%) slept less than 7 hours per night. Detailed information on sleep characteristics across groups is provided in Table **2** and Fig. (**1**).

3.3. The Comparisons of Sleep Parameters Across Groups

The comparison between the whole SCD group and the MCI group revealed significant differences in the TIB (Table **2** and Fig. **2**). The MCI group had shorter TIB compared to the whole SCD group ($p = 0.037$). There was also a tendency of differences in TST at night ($p = 0.074$) and for each 24-hour cycle (including daytime and nighttime) ($p = 0.069$). No significant differences were found to exist among the other sleep parameters.

When participants with SCD were divided into three groups, the high SCD group reported a higher PSQI total score and longer sleep latency than all the other groups, including the MCI group (Table **2** and Fig. **3**). Besides, non-parametric tests also revealed significant differences across groups on the PSQI subscales of sleep quality ($p = 0.003$), sleep latency ($p = 0.006$), sleep duration ($p = 0.011$), and sleep efficiency ($p = 0.033$) (Table **2**). Multiple comparisons (Fig. **3**) indicated the high SCD group to have significantly poorer sleep quality, longer sleep latency, shorter sleep duration, and lower sleep efficiency than the low SCD group or the moderate group. For objective sleep quality, significant differences in TIB ($p = 0.022$) and TST for each 24-hour cycle ($p = 0.029$) were revealed across groups (Table **2**). Post-hoc multiple comparisons showed that both the MCI and high SCD groups had shorter TIB and TST for each 24-hour cycle (Fig. **4**). There still existed significant or nearly significant differences after adjusting for age, gender, and SACQ score (Supplementary file **2**).

Additionally, the results also revealed the multiple-domain SCD group to have higher PSQI total scores ($p = 0.008$) and report poorer sleep quality ($p = 0.011$), shorter sleep duration ($p = 0.015$), as well as more frequently-used sleep medication ($p = 0.022$) than the single-domain SCD group (Table **3** and Fig. **5**). No significant differences in objective sleep parameters were found.

4. DISCUSSION

This study surveyed both the subjective and objective sleep quality in 207 Chinese older adults with different levels of risk for dementia through a self-reported questionnaire and ActiGraph. We divided participants with SCD into three groups according to the degree of complaints and compared the differences in sleep characteristics across the different levels of SCD groups and the MCI group. The results indicated that the MCI group tended to show poorer objectively-measured sleep quality than the SCD groups, while the self-reported sleep quality was associated with the degree of subjective cognitive complaints.

From a general view, the participants' sleep quality was not satisfactory. About half of the participants reported poor sleep, which was much higher than the overall prevalence of 14.4% among Chinese elderly people [31]. The high SCD group had the highest frequency of reporting sleep complaints on each of the subscales of PSQI. The proportion (71.3%) of participants with TST less than 7 hours was also

Table 2. Sleep characteristics of participants with SCD and MCI.

-	SCD (n=134)			SCD (*n*=134)	MCI (*n*=73)	P_a	P_b
	Low SCD (*n*=42)	Moderate SCD (*n*=50)	High SCD (*n*=42)				
Subjective Sleep Quality							
PSQI total score	6.03 (4.57)	5.38 (3.65)	9.15 (5.12)	6.76 (4.70)	6.56 (4.16)	0.727	0.001
Sleep quality	1.08 (0.92)	0.90 (0.80)	1.61 (0.92)	1.18 (0.92)	1.18 (0.86)	0.987	0.003
Sleep latency	0.90 (1.05)	0.83 (1.00)	1.59 (1.16)	1.09 (1.11)	0.90 (1.02)	0.258	0.006
Sleep duration	0.72 (0.92)	0.80 (0.81)	1.44 (1.19)	0.98 (1.02)	1.10 (0.96)	0.270	0.011
Sleep efficiency	1.46 (1.52)	0.87 (1.33)	1.82 (1.47)	1.35 (1.48)	1.40 (1.47)	0.725	0.033
Sleep disturbances	1.03 (0.63)	1.07 (0.25)	1.18 (0.56)	1.09 (0.50)	1.06 (0.51)	0.919	0.673
Sleep medication	0.41 (0.92)	0.45 (1.02)	0.93 (1.29)	0.59 (1.10)	0.50 (1.03)	0.603	0.083
Daytime dysfunction	0.49 (1.00)	0.59 (0.91)	0.74 (1.02)	0.60 (0.97)	0.44 (0.89)	0.157	0.203
Objectively Measured Sleep Quality							
TIB (min)	485.21 (71.68)	471.60 (50.04)	443.51 (58.23)	467.38 (61.58)	440.60 (50.50)	0.037	0.022
TST at night (min)	409.65 (53.88)	408.82 (47.48)	376.14 (51.78)	399.07 (52.39)	376.65 (65.07)	0.074	0.054
Sleep efficiency (%)	86.65 (4.80)	86.76 (6.57)	84.98 (5.13)	86.18 (5.58)	86.35 (5.11)	0.886	0.720
WASO (min)	61.75 (25.35)	61.37 (32.29)	63.35 (22.69)	62.10 (27.00)	57.95 (22.33)	0.783	0.894
Day nap time (min)	51.02 (40.02)	70.02 (36.80)	52.51 (30.83)	60.27 (37.56)	59.40 (34.96)	0.069	0.410
TST for each 24-hour cycle (min)	463.73 (63.21)	478.84 (45.88)	433.72 (55.32)	460.52 (56.91)	436.05 (67.47)	0.069	0.029

Abbreviations: SCD: subjective cognitive decline; MCI: mild cognitive impairment; PSQI: the Pittsburgh sleep quality index; TIB: time in bed; TST: total sleep time; WASO: wake after sleep onset. P_a means the significant difference between the SCD and the MCI group. P_b means the significant difference among the low SCD, moderate SCD, high SCD, and MCI groups.

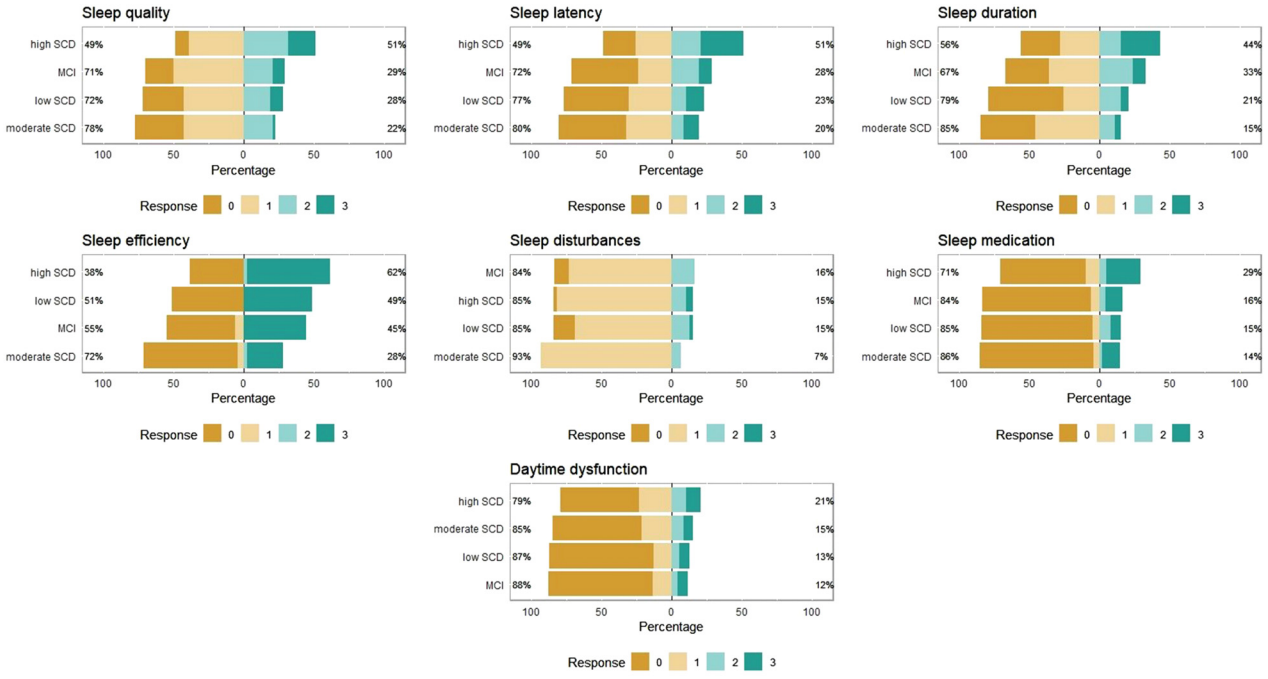


Fig. (1). The scores distribution of PSQI subscales for the different groups. **Note:** Responses of "0-3" represent the scores of each component section of PSQI. The higher one's score is, the worse one's sleep is. **Abbreviations:** PSQI: the Pittsburgh sleep quality index; SCD: subjective cognitive decline; MCI: mild cognitive impairment. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

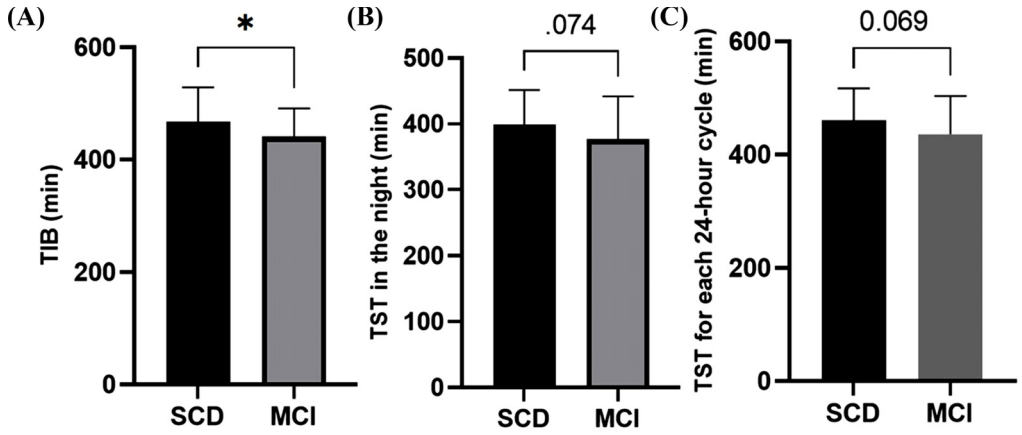


Fig. (2). The comparisons of objective sleep quality between the SCD group and the MCI group based on the independent samples T-test. **Note:** All the bars (error bars) represent means (standard deviations). * $p < 0.05$. **Abbreviations:** TIB: time in bed; TST: total sleep time; SCD: subjective cognitive decline; MCI: mild cognitive impairment. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

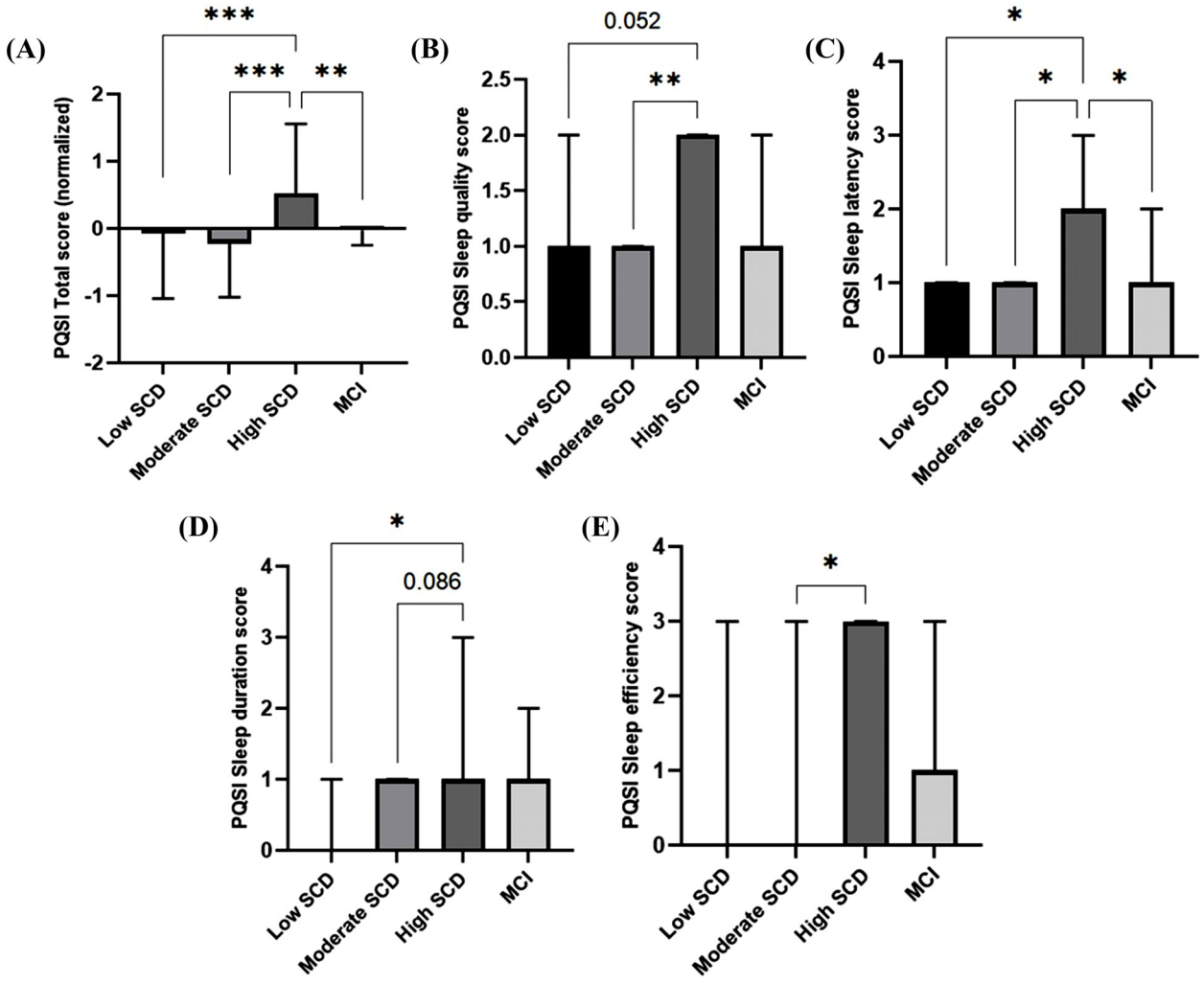


Fig. (3). The comparisons of subjective sleep quality across the four groups. **Note:** The bars (error bars) in (**A**) represent means (standard deviations), and the bars (error bars) in (**B-E**) represent medians (interquartile ranges). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. **Abbreviations:** PSQI: the Pittsburgh sleep quality index. SCD: subjective cognitive decline; MCI: mild cognitive impairment. We performed normal transformation on PSQI total score and then used one-way ANOVA for the comparative analysis among different groups. Because the scores of each component section of PSQI could not be transformed into normal data, we used the Kruskal-Wallis H test to compare the differences across the four groups. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

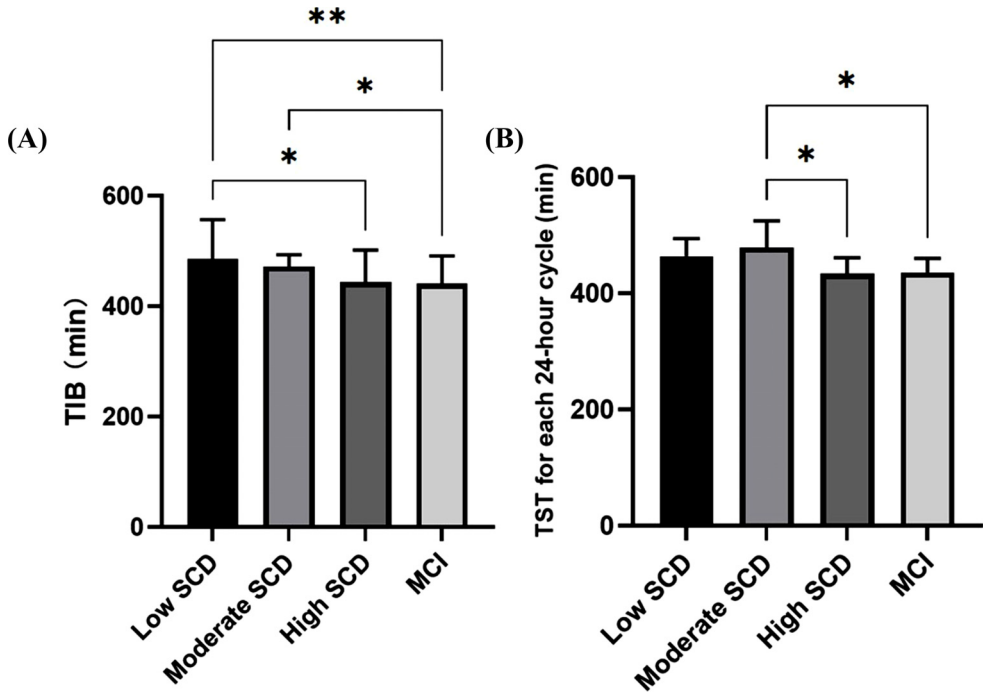


Fig. (4). (**A** and **B**) The comparisons of objectively measured sleep quality across the four groups based on one-way ANOVA. **Note:** All the bars (error bars) represent means (standard deviations). * $p < 0.05$; ** $p < 0.01$. **Abbreviations:** TIB: time in bed; TST: total sleep time; SCD: subjective cognitive decline; MCI: mild cognitive impairment. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

Table 3. Sleep characteristics of participants with SCD.

-	Single-domain SCD Group (*n* = 41)	Multiple-domain SCD Group (*n* = 93)	*p*
Subjective Sleep Quality			
PSQI total score	5.03 (3.72)	7.49 (4.90)	0.008
Sleep quality	0.87 (0.91)	1.30 (0.90)	0.011
Sleep latency	0.89 (0.95)	1.20 (1.17)	0.328
Sleep duration	0.66 (0.87)	1.17 (1.17)	0.015
Sleep efficiency	1.03 (1.42)	1.49 (1.49)	0.128
Sleep disturbances	1.00 (0.54)	1.13 (0.48)	0.129
Sleep medication	0.23 (0.67)	0.74 (1.21)	0.022
Daytime dysfunction	0.53 (0.97)	0.64 (0.97)	0.472
Objective Sleep Quality			
TIB (min)	475.14 (78.37)	463.69 (52.47)	0.498
TST at night (min)	400.54 (59.87)	398.37 (49.21)	0.881
Sleep efficiency (%)	86.53 (5.12)	86.01 (5.84)	0.735
WASO (min)	61.08 (25.64)	62.59 (27.91)	0.924
Day nap time (min)	53.42 (43.51)	63.37 (34.66)	0.804
TST for each 24-hour cycle (min)	454.59 (62.53)	463.27 (54.71)	0.587

Abbreviations: SCD: subjective cognitive decline; PSQI: the Pittsburgh sleep quality index; TIB: time in bed; TST: total sleep time; WASO: wake after sleep onset.

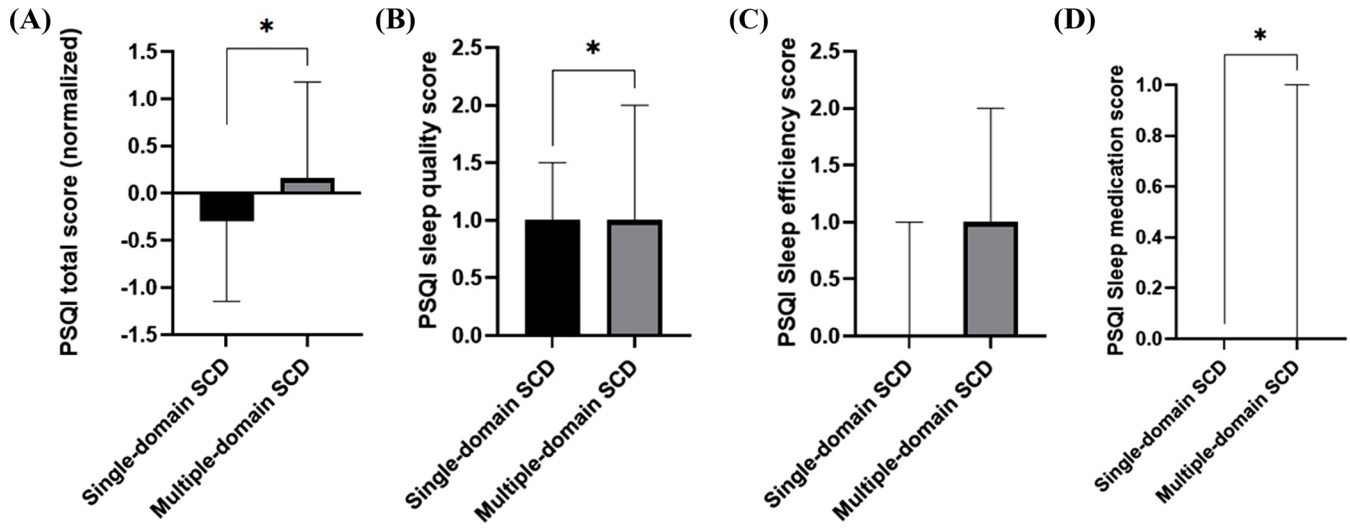


Fig. (5). The comparisons of subjective sleep quality between the single-domain group and the multiple-domain SCD group. **Note:** The bars (error bars) in (**A**) represent means (standard deviations), and the bars (error bars) in (**B-D**) represent medians (interquartile ranges). * $p < 0.05$; ** $p < 0.01$. **Abbreviations:** PSQI: the Pittsburgh sleep quality index; SCD: subjective cognitive decline. We performed normal transformation on PSQI total score and then used an independent samples T-test for the comparative analysis between groups. Because the scores of each component section of PSQI could not be transformed into normal data, we used the Mann-Whitney U test to compare the differences between the two subgroups. *(A higher resolution / colour version of this figure is available in the electronic copy of the article).*

higher than that (48.8%) in a previous population-based study among Chinese older people [32]. To some extent, our study indicated that older adults at risk for dementia had generally poorer sleep quality, either subjectively or objectively. This deserves more attention from researchers, and some measures need to be taken to improve the sleep quality of this group at risk for dementia.

The comparisons between participants with MCI or SCD revealed that the MCI group had significantly shorter TIB, and tended to show shorter TST at nighttime or for each 24-hour cycle. It implied that objectively measured sleep duration might be a potential indicator or risk factor of objective cognitive impairment. From the point of view of the biochemical mechanism, it was explainable considering that sleep state plays a critical role in the pathological process of cognitive impairment. Animal models have proven that the brain interstitial space is increased during sleep, accompanied by the enhancement in a convective exchange between cerebrospinal fluid and interstitial fluid, which could accelerate the clearance of Aβ [33]. It was reported that the clearance of Aβ during sleep increased two-fold relative to the waking state [34]. Human research also revealed lower sleep duration to be associated with reductions in cortical volume and thickness [35]. Besides, people with lower sleep duration are more likely to have some sleep disorders, such as obstructive sleep apnea, which could trigger hypoperfusion and hypometabolism of the brain, promote hippocampal atrophy, and lead to an increase in Aβ [36]. Therefore, shorter sleep duration is more likely to lead to objective cognitive decline. In addition, it has been proven that not circadian rhythm but rather the sleep-wake state itself determines the volume of the interstitial space and the efficiency of Aβ clearance [33]. Based on this view, it was also comprehensible that the MCI group tended to show shorter TST for each 24-hour cycle (including daytime and nighttime). Cognitive performance can be enhanced by the compensation of daytime napping when nighttime sleep is insufficient [37]. However, the compensation from the daytime in the MCI group seemed also to be insufficient. What deserves to be mentioned is that participants in our study generally had shorter sleep duration and only four participants slept more than eight hours per night. However, the relationship between excessive sleep and cognitive harm has not been discussed in our study.

When we performed multiple comparisons among the different levels of SCD groups and the MCI group, the high SCD group showed the highest PSQI total score and the longest sleep latency and reported poorer self-perceived sleep quality, shorter sleep duration, and lower sleep efficiency than the low or moderate SCD groups. In addition, the participants with multiple-domain SCD had poorer self-perceived sleep quality than those with single-domain SCD. It was consistent with the findings of Tsapanou *et al.* [16]. Our results suggested that sleep complaints might be an important risk factor for SCD, and the severity of sleep complaints correlates with the severity of SCD. One of the underlying causes for their correlation is probably that sleep quality and cognitive functions are sometimes affected by the same factors in old people, such as the presence of sleep-disordered breathing and insomnia [36, 38]. Considering that sleep complaints are related to an increase in the risk of future cognitive decline, older adults with a high level of SCD or multiple-domain SCD accompanying sleep complaints should be the key group for the early prevention of dementia. Given the reversibility of SCD [3], this study also reminds us that fixing sleep problems might be a helpful way to alleviate subjective cognitive complaints or prevent the progression of SCD. It should also be noted that, with the improvement of the educational and cultural level of the people on the whole, some older adults with a high level of cognitive reserve might not be easily identified at the early stage of cognitive

decline, because cognitive reserve could interact with neuropsychological parameters and mask the early clinical symptoms [39]. But these individuals can perceive their cognitive decline compared to their younger selves and report a high level of SCD. From this point of view, individuals with a high level of SCD should be paid more attention to whether they have sleep problems or not. If they have additional sleep problems, the risk of progressing toward cognitive impairment will be further increased.

In addition, our study has shown older adults with a high level of SCD to have similar objective-measured sleep characteristics to those with MCI, and both showed short TIB and TST for each 24-hour cycle. To some extent, the results imply that the individuals with a high level of SCD might have similar pathological changes to those with MCI, and have a higher risk of progression to MCI or dementia. Therefore, in future clinical practice, medical staff should not only follow up on the cognitive functions of individuals with a high level of SCD, but also pay attention to the individuals' sleep quality and take targeted measures to improve their sleep quality, such as enhancing outdoor physical activity and maintaining a regular sleep schedule. On the other hand, our findings echo those of the previous research, which demonstrated sleep dysregulation to be present before objective cognitive deterioration [40]. It seems reasonable to speculate that objectively measured sleep problems, especially shorter sleep duration, might be an early sign of cognitive impairment. But considering the limitation of the cross-sectional design in our present study, the predictive effects of sleep disturbance on the progression of SCD toward MCI deserve to be further verified in longitudinal studies. More evidence is needed to reveal whether sleep disturbance could be an early indicator for objective cognitive impairment and which sleep parameters are most valuable, specifically.

4.1. Limitations

This study involves some limitations. Firstly, the cross-sectional design with a limited sample size restricted the interpretations of the relationships between sleep and cognitive function. Secondly, most older adults willing to participate in our study tended to give positive responses when they were asked about cognitive complaints, which might cause the overinclusion of the participants with SCD and the lack of participants without SCD. Therefore, we divided the participants with SCD into three groups according to the severity of complaints to narrow the differences within the groups.

CONCLUSION

This study surveyed and compared the sleep characteristics of older adults with different levels of risk for dementia. The results demonstrated that objectively-measured shorter TIB and TST might be a potential indicator or risk factor for objective cognitive impairment. Self-reported sleep complaints were found to be associated with the severity of SCD. The older adults with a high level of SCD and multiple-domain SCD who had the worse self-perceived sleep quality should be the key group for early prevention of dementia. Treating sleep problems may be a potentially helpful way to reduce subjective cognitive complaints and prevent the progression of SCD.

LIST OF ABBREVIATIONS

Aβ	=	Amyloid-β
SCD	=	Subjective Cognitive Decline
MCI	=	Mild Cognitive Impairment
MMSE	=	Mini-Mental State Examination
PHQ-9	=	Patient Health Questionnaire-9
MoCA	=	The Montreal Cognitive Assessment
PSQI	=	Pittsburg Sleep Quality Index
TIB	=	Time in Bed
TST	=	Total Sleep Time
WASO	=	Wake After Sleep Onset
SACQ	=	Self-administered Comorbidity Questionnaire

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study has been approved by the institutional review boards of Peking University (IRB00001052-21166), China.

HUMAN AND ANIMAL RIGHTS

No animals were used for studies that are the basis of this research. All the procedures used involving human participants were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013 (http://ethics.iit.edu/ecodes/node/3931).

CONSENT FOR PUBLICATION

Oral informed consent was obtained from all participants in this study.

STANDARDS FOR REPORTING

The STROBE guidelines and methodology were followed.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available within the article.

FUNDING

This research was founded by the National Key R&D Program of China (Grant no. 2020YFC2008804), the Innovation Fund for Excellent Doctoral Students from Peking University Health Science Center (Grant no. 71013Y2136), and the Weiming Nursing Research and Innovation Fund for Leading Talents (Grant no. LJRC20YB03).

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

The authors thank all the medical staff who recommended older people to participate in their survey.

SUPPLEMENTARY MATERIAL

Supplementary material is available on the publisher's web site along with the published article.

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