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Sleep quality and cognitive functioning among Chinese older adults living in the US: a mixed-effects model analysis

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Abstract

Background Racial and ethnic disparities in sleep quality and cognitive health are increasingly recognized, yet little is understood about their associations among Chinese older adults living in the United States. This study aims to examine the relationships between sleep health and cognitive functioning in this population, utilizing data from the Population Study of Chinese Elderly in Chicago (PINE).

Methods This observational study utilized a two-wave panel design as part of the PINE, including 2,228 participants aged 65 years or older who self-identified as Chinese. Participants completed interviews at two time points. Cognitive functioning was assessed using a battery of tests, including the Chinese Mini-Mental State Examination (C_MMSE), the immediate and delayed recall of the East Boston Memory Test, the Digit Span Backwards assessment, and the Symbol Digit Modalities Test. Sleep quality was assessed using items from the Pittsburgh Sleep Quality Index (PSQI), covering four aspects: subjective sleep quality, sleep latency, sleep efficiency, and sleep duration. Insomnia was assessed using four items from the Women's Health Initiative Insomnia Rating Scale. Mixed-effects regression models were used to assess the effects of sleep parameters on baseline cognitive functioning and cognitive change over time.

Results Participants had an average age of 77.42 years (± 7.57) at baseline, with about 39% reporting fairly bad or very bad sleep quality. Poorer overall sleep quality (B = -0.01, SE = 0.01, p < .01), and more insomnia symptoms (B = -0.01, SE = 0.00, p < .001) were associated with lower baseline global cognition. However, these associations diminished over time (sleep quality: B = 0.01, SE = 0.00, p < .05; insomnia: B = 0.00, SE = 0.00, p < .05). Among sleep quality subdomains, all except sleep efficiency had significantly negative relationships with baseline global cognition. The associations between sleep parameters and the four cognitive domains were less consistent.

Conclusions The findings highlight cross-sectional negative relationships between self-reported sleep parameters and cognition, showing distinct associations between various aspects of sleep quality and cognitive domains. Targeted interventions to improve sleep quality may have the potential to enhance cognitive health outcomes.

Keywords Sleep health, Cognition, Older Chinese americans, Mixed-effects models

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Background

Sleep problems and cognitive decline are common among older adults. Although it is well established that sleep plays a crucial role in cognitive functioning and memory consolidation [1], the extent to which sleep problems predict poor cognitive functioning in later life remains unclear [1, 2]. Health disparities based on race and ethnicity may further complicate the relationship between sleep and cognition [3]. Increasing evidence suggests racial and ethnic disparities in sleep quality and cognitive health [3–5], yet little is known about their associations among older Chinese Americans, a rapidly growing population.

As individuals age, their sleep patterns often undergo changes, including reduced total sleep duration and efficiency, increased sleep fragmentation, difficulty falling asleep, decreased time in rapid eye movement sleep and in slow-wave sleep [6]. It is estimated that up to 50% of older adults frequently experience difficulty initiating or maintaining sleep, and about 40–70% report chronic sleep problems [7, 8]. These sleep problems have significant health implications in old age, including poor self-reported health, depression, cognitive decline, limitations in daily activities, reduced quality of life, and heightened risk of institutionalization [7].

Emerging evidence suggests connections between self-reported sleep problems and cognitive functioning in older adults living in the community [1, 9, 10]. However, among healthy older adults, the associations between sleep problems and cognitive functioning are not always apparent [10]. Studies yielding null results may be attributed to the selection of different cognitive tests, imprecise measures of cognitive functioning, or inadequate assessment and analysis of sleep patterns [3, 10, 11]. Self-reported sleep measures include sleep latency (time to sleep onset), wake after sleep onset, sleep efficiency (ratio of hours slept to hours spent in bed), sleep duration, and general sleep complaints [9]. Cognition tests typically assess executive function, attention, episodic memory, working memory, and processing speed, which collectively indicate global cognitive functioning [9]. Multiple measures of sleep may have differential associations with cognitive functioning and its various domains. Previous studies have documented that long sleep latency and duration, poor sleep efficiency and quality, and excessive daytime sleepiness are associated with cognitive impairment in later life; however, findings on these associations have been inconsistent [10, 12, 13]. Therefore, further research, especially with longitudinal designs, is essential to clarify the associations between specific aspects of sleep quality and various cognitive domains.

As poor sleep health is not an integral part of the aging process, its impact varies among adults and can disproportionately affect the cognitive health of racially and ethnically marginalized groups, including Chinese Americans [3, 14]. Chinese Americans account for 24% of the Asian American population, with 30% having migrated after age 60 [15]. Many older Chinese Americans experience acculturative stress due to language barriers, social isolation, intergenerational differences in cultural values, and limited access to health services [11, 14]. These factors are associated with negative health outcomes, such as anxiety, depression, and sleep disturbances [3, 14, 16]. Limited studies indicate that older Chinese Americans tend to report poorer sleep quality, including shorter sleep duration, lower sleep quality, and longer sleep onset, compared to their White counterparts [14, 16]. Although the specific prevalence of cognitive impairment among older Chinese Americans remains understudied [17], evidence suggests that Asian Americans may experience similar or higher rates of cognitive impairment and dementia compared to White older adults [18]. Data from the PINE study reveal a baseline cognitive impairment prevalence of 7.6% and a two-year incidence rate of 5.1% among community-dwelling older Chinese Americans [19]. The combined effects of age-related changes, acculturative stress, and sleep disturbances may further exacerbate cognitive impairment in this population.

Several studies focusing on Asian Americans have revealed the heterogeneity in the relationships between sleep and cognitive functioning across racial and ethnic groups [14, 16, 20]. However, the nuanced associations between sleep problems and cognitive health warrant further investigation within each ethnic group [3]. To our knowledge, no study has specifically addressed older Chinese Americans, despite their considerable population growth and unique health disparities. Given the limited research on this population and the inconsistent findings in broader older populations, it is important to improve our understanding of the relationship between sleep problems and cognitive functioning among older Chinese Americans to help reduce health disparities. Therefore, the present study aims to investigate the associations between sleep parameters and various domains of cognitive functioning among Chinese older adults, using data from the Population Study of Chinese Elderly in Chicago (PINE). It is hypothesized that poorer sleep quality and more insomnia symptoms are associated with lower levels of baseline cognition and faster rates of cognitive decline over time.

Methods

Study design and sample

This observational study utilized a two-wave panel design as part of the PINE, a population-based, epidemiological study examining sociocultural determinants of health among older Chinese adults in the US. Recruitment for PINE was conducted through collaboration with over

20 community-based social service agencies and organizations in the Greater Chicago area. Eligibility criteria included adults aged 60 and older who self-identified as Chinese and resided in the area. Individuals younger than 60 and those who did not self-identify as Chinese were excluded from the study recruitment.

Eligible older adults were approached through routine social services and outreach efforts serving Chinese American families in Chicago and its suburban areas. Additional recruitment strategies included word of mouth, as well as announcements and advertisements in newsletters and public spaces. Eligible older adults who agreed to participate were surveyed in their preferred language and dialects, such as Mandarin, Cantonese, Taishanese, or English. Written consent was obtained from all participants. A comparison with the Census data indicated that the PINE study was representative of the Chicago Chinese aging population, with no significant differences in key sociodemographic characteristics [21]. This analysis included 2,228 participants aged 65 years or older, who completed the interview between 2017 and 2019 (baseline or T1), during which sleep measures were first introduced, and participated in follow-up interviews between 2019 and 2021 (T2).

The PINE study was approved by the Institutional Review Board at Rush University Medical Center in Chicago, Illinois (IRB#: 10090203). This secondary analysis of the PINE study was approved by Institutional Review Boards at the University of Pittsburgh (IRB#: EXT20030031) and Rutgers, The State University of New Jersey (IRB#: Pro2018001578).

Measurement

Cognitive functioning

A battery of cognitive tests was administered to assess participants' cognitive functioning across various domains. *Perceptual speed* was assessed using the oral version of the 11-item Symbol Digit Modalities Test (SDMT), which calls for rapid perceptual comparisons of numbers and symbols within a 90-second duration [22]. *Episodic memory* was assessed using a combined score from two tests: the East Boston Memory Test-Immediate Recall (EBMT) and the East Boston Memory Test-Delayed Recall (EBDR) of brief stories [23]. *Working memory* was assessed using the Digit Span Backwards Test (DB), drawn from the Wechsler Memory Scale-Revised Test [24]. The fifth test in the battery, the 30-item Chinese Mini-Mental State Examination (C-MMSE), adapted from the widely used MMSE, was included to measure general cognitive ability [25]. The *C-MMSE* has been validated in older adults in Hong Kong [25]. Higher scores across all tests indicated better cognitive performance. Lastly, a *global cognition* score was calculated by averaging standardized scores from these five tests to reduce floor and ceiling effects and other measurement errors (Cronbach's $\alpha = 0.87$) [26].

Sleep parameters

Sleep parameters included overall sleep quality with four components, and insomnia. *Overall sleep quality* was assessed using items from the Pittsburgh Sleep Quality Index (PSQI) to measure four components: subjective sleep quality, sleep latency, sleep efficiency, and sleep duration [27]. The PSQI is a validated and extensively adopted instrument to evaluate subjective sleep quality among older adults [28–31]. *Subjective sleep quality* was assessed with one question: "During the past month, how would you rate your sleep quality overall?" Responses were given on a 4-point scale, ranging from 0 (very good) to 3 (very bad). *Sleep latency* was measured with one question asking about the time it takes to fall asleep. Responses were categorized into 0 (≤15 min), 1 (>15 to ≤30 min), 2 (>30 to ≤60 min), or 3 (>60 min). Based on responses to four questions, *sleep efficiency* was calculated as the actual hours of sleep time divided by the total hours in bed and multiplied by 100. It was recoded as 0 (≥85%), 1 (≥75% to <85%), 2 (≥65% to <75%), or 3 (<65%). *Sleep duration* was measured by the actual hours slept at night, which was further recoded on as 0 (≥7 h), 1 (<7 to ≥6 h), 2 (<6 to ≥5 h), or 3 (<5 h). The component scores were summed to form a global PSQI score ranging from 0 to 12, with higher scores indicating poorer sleep quality (Cronbach's $\alpha = 0.75$).

Insomnia was measured using four items adapted from the Women's Health Initiative Insomnia Rating Scale (WHIIRS). The WHIIRS is a reliable and valid tool for assessing perceived insomnia severity in older adults [32, 33]. Participants were asked how often, over the past month, they experienced the following: difficulty falling asleep, waking up at night and being unable to get back to sleep, waking up too early in the morning and being unable to get back to sleep, and feeling excessively sleepy during the day. Each item was scaled on a 5-point scale ranging from 0 (never) to 4 (almost always). A sum score, ranging from 0 to 16, was calculated, with higher scores indicating more severe insomnia (Cronbach's $\alpha = 0.83$). In addition, the item on *daytime sleepiness* was excluded from the sum score to control for its effects in the models with the PSQI and its subdomains.

Covariates

Time was indicated by baseline (0) and follow-up (1). Sociodemographic covariates included *age*, *sex*, *married status*, *education*, and *annual income*. Immigration-related variables included *years living in the US* and *acculturation*. Acculturation was measured using 12 items adapted from the Short Acculturation Scale for Hispanics [34], which assessed individual preferences

in language use, media use, and ethnic social relations. Responses were given on a 5-point scale, from 1 (only Chinese) to 5 (only English). The summary score ranged from 12 to 60, with higher scores indicating a higher level of acculturation (Cronbach's $\alpha = 0.92$).

We also controlled for health behaviors and health-related variables thought to relate to cognitive functioning. Health behaviors included *alcohol use* and *physical performance*. Alcohol use was calculated as the average daily consumption of alcoholic beverage. Physical performance was assessed with the Basic Physical Activities (NAGI) Scale [35], which evaluates the difficulty of performing physical activities, such as pushing large objects, stooping, crouching or kneeling, lifting or carrying weights over 10 pounds, reaching or extending arms above shoulder level, and handing or fingering small objects (Cronbach's $\alpha = 0.80$). A higher score indicated greater difficulty in performing physical activities. Health-related variables included body mass index (*BMI)*, depressive symptoms, and instrumental activities of daily living (IADLs). BMI is defined as the body mass divided by the square of the body height, expressed in unit of kg/m^2. It was categorized as normal (< 25), overweight (≥ 25 to < 30), and obese (≥ 30) [36]. Depressive symptoms were assessed using the Patient Health Questionnaire [37], excluding the question regarding respondents' sleep disturbance experience (Cronbach's $\alpha = 0.78$). IADLs were assessed with a scale measuring the difficulty in performing various instrumental activities of daily living [38] (Cronbach's $\alpha = 0.90$).

Statistical analysis

Mixed-effects regression models were estimated to assess initial status and changes in cognitive functioning and the predictive effects of sleep parameters after adjusting for sociodemographic variables, health behaviors, and health-related covariates. The models used sleep measures and covariates from T1, and cognitive measures from both time points. Fixed effects were used to determine whether the average change in the outcome variable was associated with a one-unit change in a predictor variable [39]. Random effects represent the general variability among subjects [39]. The effect of time was entered as a fixed factor to capture potential differences in cognitive functioning between the two time points. Sleep parameters, covariates, and their interactions with time were entered as fixed effects to assess their associations with the initial level of cognition and the rate of change. Given that two data points might not adequately illustrate a change trend, random intercept models were specified to allow for individual-specific means varying around the sample mean intercept [39]. For each cognitive outcome, six mixed-effects regression models were estimated, with one sleep parameter and its interaction with time being entered, respectively. At T2, the majority of respondents (88.2%) were interviewed in 2019. Sensitivity analyses were conducted by rerunning the mixed-effects regression analyses, excluding those who completed the T2 assessment after March 21, 2020 (the date Illinois issued a stay-at-home order due to COVID-19) ($n = 90$). All continuous variables were mean-centered to prevent multicollinearity. The analyses were performed using Stata 18.0 [40].

Results

Table 1 presents the characteristics of the study participants. The mean age of participants was 77 years ($SD = 7.6$), with 60% being female. On average, participants had resided in the US for 25 years ($SD = 12.0$), and the mean acculturation score was 14.6 ($SD = 3.8$). The reported average PSQI score was 4.1 ($SD = 3.1$), and the mean insomnia score was 5.5 ($SD = 4.2$). Over 60% of participants reported either good or very good sleep quality. They reported relatively few depressive symptoms ($M = 1.5$, $SD = 2.8$), and had an average IADL score of 6.4 ($SD = 7.8$).

Table 2 presents the results of six mixed-effects regression models examining global cognition. The estimates of time and covariate effects reported here were derived from the model using PSQI to predict both baseline and the rate of change in global cognition (Model 1). Four out of six full models did not reveal any significant change in global cognition over the 2-year observation period, except in the models using a single item of subjective sleep quality and sleep duration (see Additional File 1). Overall, significant negative associations were observed between sleep parameters and global cognition cross-sectionally. Poorer overall sleep quality, as indicated by the PSQI (Model 1: B = -0.01, $SE = 0.01$, $p < .01$), and more insomnia symptoms (Model 2: B = -0.01, $SE = 0.00$, $p < .001$) were associated with lower baseline cognitive functioning, respectively. Among the subdomains in the PSQI, all except sleep efficiency were significantly related to baseline cognition. Specifically, respondents reporting very bad sleep quality exhibited worse global cognition scores compared to those reporting very good sleep quality (Model 3: B = -0.28, $SE = 0.06$, $p < .001$). Similarly, those taking longer to fall asleep (30 to 60 min) showed lower global cognition scores compared to those falling asleep within 15 min (Model 4: B = -0.13, $SE = 0.04$, $p < .01$). Those sleeping less than five hours per night demonstrated lower global cognition scores (Model 6: B = -0.09, $SE = 0.04$, $p < .05$), while those sleeping between 6 and 7 h had higher scores (Model 6: $B = 0.07$, $SE = 0.03$, $p < .05$) compared to those sleeping over seven hours.

Contrary to the study hypothesis, sleep parameters were not associated with cognitive decline over time. Instead, the study found positive time interactions with

Table 1 Sample characteristics of participants at T1 ($N = 2,228$)

Characteristics	Mean (SD)/*n*(%)[a]	Min	Max
Age	77.42 (7.57)	65	103
Female	1,331 (59.74%)	0	1
Married	1,437 (64.50%)	0	1
Education	8.84 (5.00)	0	26
Income	2.03 (1.08)	1	10
Years living in the US	24.54 (12.01)	5.71	95.67
Acculturation	14.57 (3.83)	12	54
Alcohol use (amount/day)	0.02 (0.07)	0	1.02
Physical performance	5.95 (5.60)	0	20
BMI categories			
Normal	1,585 (71.36%)	1	3
Overweight	553 (24.90%)		
Obese	83 (3.74%)		
Depressive symptoms	1.50 (2.78)	0	22
IADLs*	6.42 (7.85)	0	36
Daytime sleepiness		1	5
Never	1,064 (47.78%)		
Rarely	299 (13.43%)		
Sometimes	468 (21.01%)		
Often	253 (11.36%)		
Almost always	143 (6.42%)		
Overall sleep quality (PSQI)	4.13 (3.05)	0	12
Subjective sleep quality		0	3
Very good	226 (11.94%)		
Fairly good	1,101 (49.42%)		
Fairly bad	673 (30.21%)		
Very bad	188 (8.44%)		
Sleep latency		0	3
≤ 15 min	875 (39.27%)		
> 15 to ≤ 30 min	691 (31.01%)		
> 30 to ≤ 60 min	**405 (18.18%)**		
> 60 min	**257 (11.54%)**		
Sleep efficiency		**0**	**3**
≥ 85%	**1,347 (60.76%)**		
≥ 75% to < 85%	**346 (15.61%)**		
≥ 65% to < 75%	**212 (9.56%)**		
< 65%	**312 (14.07%)**		
Sleep duration		0	3
>=7 h	1,058 (47.64%)		
< 7 to >= 6 h	489 (22.02%)		
< 6 to >= 5 h	354 (15.94%)		
< 5 h	320 (14.41%)		
Insomnia symptoms	5.50 (4.24)	0	16
Global cognition	-0.37 (0.95)	-3.12	1.63
Perceptual speed	-0.42 (1.03)	-2.36	3.16
Episodic memory	-0.36 (1.09)	-2.85	1.29
Working memory	-0.20 (0.95)	-2.15	2.94
C_MMSE	-0.50 (1.37)	-5.72	1.02

Note BMI: Mody Mass Index. IADLs: Instrumental activities of daily living. C_MMSE: Chinese Mini-Mental State Examination. PSQI: Pittsburgh Sleep Quality Index

PSQI, insomnia, and subjective sleep quality. That is, these sleep measures were associated with slower rates of decline in global cognition, indicating a reduced impact of sleep problems on cognitive functioning as time progressed. Among the covariates, older age, lower levels of education and acculturation, more difficulties in physical performance, and more limitations in IADLs were associated with worse cognitive functioning at baseline. Additionally, significant associations were observed between age, education, and cognitive decline, indicating that older age and higher levels of education were linked to accelerated cognitive decline. Interestingly, overweight respondents exhibited better functioning compared to those with normal weight. Daytime sleepiness showed inconsistent effects: respondents reporting sometimes feeling drowsy during the day had worse cognitive performance compared to those reporting never feeling drowsy, while those reporting always feeling drowsy exhibited better cognitive performance.

Table 3 presents the mixed-effects model estimates of sleep measures in relation to four cognitive domains after controlling for covariates. Similar to the results for global cognition, significant negative relationships were found cross-sectionally between sleep parameters and cognitive measures. Specifically, poorer sleep quality, either measured by PSQI or the single item, was associated with worse status in most domains. More insomnia symptoms were related to poorer perceptual speed and episodic memory. Long sleep latency was associated with worse functioning in all domains except the C_MMSE. Sleep efficiency showed inconsistent associations with various domains, while sleep duration was not significantly related to any domains. Over time, the negative effects of sleep quality may diminish in certain domains, particularly working memory and the C_MMSE. The effects of covariates remained consistent across models (detailed results available upon request). The sensitivity analyses largely confirmed the significant cross-sectional associations between sleep parameters and cognitive functioning. However, the effects of PSQI and insomnia on the rate of cognitive change were either barely or non-significant statistically (Additional File 2).

Discussion

The current study examined the associations between sleep parameters and cognitive functioning in the largest population-based epidemiological study of US Chinese older adults. Consistent with previous studies [3, 9, 10], our findings generally supported cross-sectional negative relationships between self-reported sleep parameters and the domains of cognition and global cognition among older Chinese Americans. Self-reported sleep quality, whether assessed through the PSQI scale or one of its

Table 2 Fixed effects of associations between sleep parameters and global cognition

Predictors	Coefficient (SE)	*p*
Model 1		
Time	-0.02 (0.02)	0.28
Age	-0.02 (0.00)	< 0.001
Age*time	-0.00 (0.00)	< 0.01
Female	0.05 (0.03)	0.12
Female*time	-0.02 (0.01)	0.15
Married	0.05 (0.03)	0.11
Married*time	0.02 (0.02)	0.13
Education	0.08 (0.00)	< 0.001
Education*time	-0.00 (0.00)	< 0.05
Income	0.01 (0.01)	0.54
Income*time	-0.00 (0.01)	0.83
Acculturation	0.02 (0.00)	< 0.001
Acculturation*time	0.00 (0.00)	0.61
Years in the US	0.00 (0.00)	0.60
Years in the US*time	0.00 (0.00)	0.23
Physical performance	-0.03 (0.00)	< 0.001
Physical performance*time	0.00 (0.00)	0.52
Alcohol use	-0.03 (0.20)	0.90
Alcohol use*time	0.09 (0.10)	0.37
BMI		
Normal (ref)		
Overweight	0.08 (0.03)	< 0.01
Obese	-0.03 (0.07)	0.65
BMI*time		
Normal (ref)		
Overweight	-0.00 (0.02)	0.97
Obese	0.04 (0.03)	0.28
Depression	-0.01 (0.01)	0.09
Depression*time	0.00 (0.00)	0.12
IADL	-0.03 (0.00)	< 0.001
IADL*time	0.00 (0.00)	0.66
Daytime sleepiness[a]		
Never (ref)		
Rarely	-0.04 (0.04)	0.34
Sometimes	-0.09 (0.04)	< 0.05
Often	-0.08 (0.05)	0.08
Almost always	0.13 (0.06)	< 0.05
Daytime sleepiness*time[a]		
Never (ref)		
Rarely	0.01 (0.02)	0.75
Sometimes	-0.01 (0.02)	0.55
Often	0.04 (0.02)	0.09
Almost always	-0.03 (0.03)	0.27
PSQI	-0.01 (0.01)	< 0.01
PSQI*time	0.01 (0.00)	< 0.05
Model 2		
Insomnia	-0.01 (0.00)	< 0.001
Insomnia*time	0.00 (0.00)	< 0.05
Model 3		
Subjective sleep quality		
Very good (ref)		
Fairly good	-0.04 (0.04)	0.35

Table 2 (continued)

Predictors	Coefficient (SE)	*p*
Fairly bad	-0.04 (0.05)	0.42
Very bad	-0.28 (0.06)	< 0.001
Subjective sleep quality*time		
Very good (ref)		
Fairly Good	0.06 (0.02)	< 0.01
Fairly Bad	0.05 (0.02)	< 0.05
Very Bad	0.09 (0.03)	< 0.01
Model 4		
Sleep latency		
<=15 min (ref)		
15–30 min	0.05 (0.03)	0.09
30–60 min	-0.13 (0.04)	< 0.01
>60 min	-0.08 (0.05)	0.09
Sleep latency*time		
<=15 min (ref)		
15–30 min	0.01 (0.02)	0.74
30–60 min	0.02 (0.02)	0.31
>60 min	-0.00 (0.02)	0.97
Model 5		
Sleep efficiency		
>=85% (ref)		
75–85%	0.05 (0.04)	0.16
65–75%	0.05 (0.05)	0.32
<65%	-0.08 (0.04)	0.06
Sleep efficiency*time		
>=85% (ref)		
75–85%	0.00 (0.02)	0.99
65–75%	0.01 (0.02)	0.60
< 65%	0.02 (0.02)	0.30
Model 6		
Sleep duration		
>=7 h (ref)		
6–7 h	0.07 (0.03)	< 0.05
5–6 h	-0.02 (0.04)	0.62
<5 h	-0.09 (0.04)	< 0.05
Sleep duration*time		
>=7 h (ref)		
6–7 h	0.03 (0.02)	0.07
5–6 h	0.04 (0.02)	< 0.05
<5 h	0.04 (0.02)	0.07

Note Model 2 controlled for all covariates except daytime sleepiness and the interaction between daytime sleepiness and time, considering daytime sleepiness as one item measuring insomnia. Models 3 to 6 controlled for all covariates as those in Model 1. Results for covariates in Models 2–6 were not displayed for simplicity

individual items, demonstrated significant associations with cognitive measures.

Specifically, individuals reporting very poor subjective sleep quality demonstrated lower scores on working memory, episodic memory, and the C_MMSE, although no difference in perceptual speed was observed between them and those reporting very good sleep quality. This aligns with a previous study that found no difference in information-processing speed between poor and good sleepers among community-dwelling, healthy older Americans [41]. However, other sleep parameters, including the PSQI, insomnia symptoms, sleep latency, and sleep efficiency, were significantly related to perceptual speed. These findings suggest that a single self-rated sleep quality item may not adequately reflect the disruptions of slow-wave sleep and sleep continuity that are linked to reduced processing speed [42].

The current study revealed distinct associations between various aspects of sleep quality and cognitive domains. Long sleep latency, indicating more difficulty

Table 3 Fix effects of associations between sleep parameters and cognitive domains

	Perceptual speed	Working memory	Episodic memory	C_MMSE
Predictors	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
Models: PSQI + Covariates				
Time	-0.04 (0.02)	-0.02 (0.02)	0.02 (0.03)	-0.07 (0.03)*
PSQI	-0.01 (0.01)*	-0.02 (0.01)**	-0.02 (0.01)*	-0.01 (0.01)
PSQI*time	0.00 (0.00)	0.01 (0.00)*	0.00 (0.00)	0.01 (0.00)*
Models: Insomnia + Covariates				
Time	-0.03 (0.02)	-0.03 (0.02)	0.03 (0.03)	-0.09 (0.03)**
Insomnia	-0.02 (0.00)***	-0.01 (0.00)	-0.02 (0.00)***	0.00 (0.01)
Insomnia*time	0.00 (0.00)*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Models: Subjective sleep quality + Covariates				
Time	-0.05 (0.03)	-0.14 (0.03)***	-0.02 (0.04)	-0.14 (0.04)**
Sleep quality				
Very good (ref)				
Fairly good	0.03 (0.05)	-0.12 (0.05)*	-0.06 (0.06)	0.00 (0.07)
Fairly bad	0.03 (0.06)	-0.14 (0.06)*	-0.04 (0.07)	-0.03 (0.07)
Very bad	-0.08 (0.08)	-0.24 (0.08)**	-0.37 (0.09)***	-0.32 (0.10)**
Sleep quality*time				
Very good (ref)				
Fairly Good	0.01 (0.02)	0.12 (0.03)***	0.05 (0.03)	0.06 (0.03)
Fairly bad	0.00 (0.03)	0.13 (0.03)***	0.04 (0.04)	0.06 (0.04)
Very bad	0.02 (0.04)	0.16 (0.04)***	0.08 (0.05)	0.10 (0.05)*
Models: Sleep latency + Covariates				
Time	-0.04 (0.02)	-0.04 (0.03)	0.02 (0.03)	-0.09 (0.03)**
Sleep latency				
<=15 min (ref)				
15–30 min	0.01 (0.04)	0.05 (0.04)	0.07 (0.04)	0.06 (0.05)
30–60 min	-0.16 (0.05)***	-0.08 (0.05)	-0.16 (0.05)**	-0.09 (0.06)
>60 min	-0.12 (0.05)*	-0.13 (0.06)*	-0.07 (0.06)	0.01 (0.07)
Sleep latency*time				
<=15 min (ref)				
15–30 min	0.00 (0.02)	0.01 (0.02)	0.00 (0.02)	0.01 (0.03)
30–60 min	0.01 (0.02)	0.02 (0.03)	0.01 (0.03)	0.03 (0.03)
>60 min	-0.05 (0.03)	0.04 (0.03)	-0.02 (0.04)	0.01 (0.04)
Models: Sleep efficiency + Covariates				
Time	-0.05 (0.02)*	-0.04 (0.03)	0.02 (0.03)	-0.09 (0.03)**
Sleep efficiency				
>=85% (ref)				
75–85%	-0.02 (0.04)	0.01 (0.05)	0.10 (0.05)*	0.07 (0.06)
65–75%	0.07 (0.05)	-0.04 (0.06)	0.04 (0.06)	0.14 (0.07)*
<65%	-0.11 (0.05)*	-0.05 (0.05)	-0.07 (0.06)	-0.10 (0.06)
Sleep efficiency*time				
>=85% (ref)				
75–85%	0.00 (0.02)	0.01 (0.02)	-0.02 (0.03)	0.02 (0.03)
65–75%	-0.02 (0.03)	0.03 (0.03)	0.01 (0.04)	0.04 (0.04)
< 65%	0.05 (0.02)*	0.01 (0.03)	0.01 (0.03)	0.04 (0.03)
Models: Sleep duration + Covariates				
Time	-0.05 (0.02)*	-0.04 (0.03)	0.01 (0.03)	-0.10 (0.03)**
Sleep duration				
>=7 h (ref)				
6–7 h	0.04 (0.04)	0.06 (0.04)	0.09 (0.05)	0.07 (0.05)
5–6 h	-0.02 (0.05)	-0.04 (0.05)	-0.01 (0.05)	-0.04 (0.06)
<5 h	-0.08 (0.05)	-0.10 (0.05)	-0.10 (0.06)	-0.06 (0.07)
Sleep duration*time				

Table 3 (continued)

	Perceptual speed	Working memory	Episodic memory	C_MMSE
Predictors	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
>=7 h (ref)				
6–7 h	0.03 (0.02)	0.03 (0.02)	0.03 (0.03)	0.06 (0.03)*
5–6 h	0.01 (0.02)	0.04 (0.03)	0.04 (0.03)	0.07 (0.03)*
<5 h	0.03 (0.03)	0.03 (0.03)	0.05 (0.03)	0.05 (0.03)

Note All models controlled for every covariate, except for excluding daytime sleepiness from the models that utilized insomnia to predict cognitive outcomes

*$p < .05$, **$p < .01$, *** $p < .001$

in initiating sleep, was significantly associated with worse global cognition, perceptual speed, episodic memory, and working memory. In contrast, sleep duration was only linked to global cognition, while sleep efficiency was solely related to perceptual speed. The absence of significant effects of sleep efficiency on other domains of cognitive functioning suggests that it may not be a critical factor in cognitive performance in this study sample. Moreover, sleep efficiency, defined as the ratio of actual sleep time to total time in bed, may be susceptible to measurement error due to deficiencies in attention, task-switching, and cognitive flexibility [43]. This could explain its significant relationship with perceptual speed but no other cognitive domains [43]. Consistent with previous research indicating that sleep durations shorter or longer than 6–7 h were associated with worse cognitive functioning [8], the current study found that sleeping for 6–7 h may be optimal for global cognition, although not necessarily for specific domains. This observation could be explained by the notion that the most critical aspect of sleep quality may be the amount of unwanted intruding wakefulness experienced, rather than the total duration of sleep [41]. Long sleep may indicate underlying diseases and failing health, whereas inadequate sleep may be linked to cardiovascular and/or cerebrovascular disease, stroke, metabolic syndrome, diabetes, and depression – all of which are known contributors to an increased risk of cognitive decline [44].

The study did not find significant time effect of sleep parameters on cognitive decline, with some findings even contradicting the study hypothesis. Specifically, the negative associations of poor sleep quality with global cognition and working memory appeared to weaken over the two-year observation period. This could be attributed to the relatively short duration of the study, insufficient to capture a meaningful declining trend. Among the cognitive measures, only the C_MMSE consistently exhibited a decline across the analysis models. These findings suggest that chronic sleep problems, rather than short-term fluctuations, may be more strongly linked to cognitive decline. Additionally, the association between sleep and cognition might weaken with age, as the aging brain may become less efficient in supporting sleep-specific cognitive processes [10]. For older adults experiencing chronic sleep disturbances or deprivation, the impact of additional sleep may be minimal [10]. This could explain findings where insomnia, a condition marked by chronic sleep problems, was not associated with cognitive decline, as well as the contradictory effects observed for low sleep efficiency and daytime sleepiness. Moreover, these contradictory findings could be influenced by individual differences in cognitive status. For some older adults, cognitive capacity may shape their perceptions of sleep quality and quantity over the past month. Poor sleep quality, characterized by long sleep latency and low sleep efficiency, might not necessarily act as a risk factor for cognitive decline but instead serve as an early marker of neurodegeneration in non-demented individuals [45]. Additionally, some older adults may demonstrate greater resistance to the cognitive effects of sleep disturbances, possibly due to physiological adaptations associated with aging [9].

These potential explanations may also account for discrepancies in the time effects documented in the limited research available on other racial and ethnic groups. For instance, a few studies conducted among older Koreans [46] and older Japanese individuals [47] in their home countries found significant associations between sleep problems, such as long sleep latency and extended sleep duration, and faster cognitive decline over time. Similarly, scant evidence from studies of older Mexicans and older Black Americans also suggests the long-term negative effects of sleep problems on cognitive decline [3, 48]. These discrepancies highlight the need for future research to explore cultural differences, environmental factors, or genetic variations that may influence sleep patterns and cognitive aging.

Several limitations of this study should be noted. First, this analysis focused on community-dwelling older adults. While some participants remained relatively healthy and high-functioning, those with severe cognitive and physical impairments may have been unable to participate in the PINE study. This health selection bias could result in an underestimation of the negative effects of sleep problems. Second, the study relied solely on self-reported measures of sleep problems. Although subjective measures of sleep have been inconsistently linked to poorer cognitive functioning [10], they are prone to

differential misclassification and selective dropout. Participants with cognitive impairments may struggle to accurately answer sleep questions [9]. Additionally, the PSQI, used to measure sleep quality, may not be entirely suitable for older adults. This is because it relies on cognitive capacity to recall sleep patterns over the past month, which can be challenging for individuals with declining cognitive function [49]. This potential bias is particularly concerning in the context of long-term cognitive decline.

Further, the study did not account for the potential confounding factors such as obstructive sleep apnea and medication use. Participants with undiagnosed sleep apnea, which was neither screened for nor diagnosed, may have contributed to inconsistencies in the observed associations between self-reported sleep problems and cognitive functioning [9]. Additionally, the PINE study did not assess the use of medications that could influence either sleep or cognitive performance. Since medication use may confound the relationship between sleep quality and cognition, it is important to examine the impact of sleep medication use, particularly among racial and ethnic groups historically underrepresented in cognitive aging research [3]. Lastly, the average two-year follow-up period was relatively short. This limited duration might have constrained our ability to detect cognitive decline and the effects of sleep problems. Future research should aim to overcome these limitations by applying longitudinal research designs, incorporating health screening and diagnosis, and integrating reliable and valid objective measures of sleep. These approaches will enable a more thorough understanding of changes in sleep patterns and cognitive functioning, as well as the factors influencing the association between sleep and cognition over time.

Conclusion

The current study examined multiple facets of subjective sleep measures in relation to global cognition and specific cognitive domains. The findings underscored the significant associations between sleep quality, as measured by the PSQI and a single self-reported item, and various aspects of cognitive functioning. Specifically, long sleep onset latency appeared to be linked to potential impairment in episodic memory, perceptual speed, and global cognition. Given the high prevalence of sleep disturbances and cognitive disorders among older adults, understanding the relationship between sleep health and cognitive aging holds significant public health implications. Targeting individuals at risk of cognitive decline through interventions aimed at improving sleep quality could potentially enhance cognitive health outcomes. Moreover, considering the racial and ethnic disparities in sleep and cognitive health, coupled with the limited research among older Chinese Americans, there is a pressing need for longitudinal and interventional studies to mitigate health inequities in this minority population. Older Chinese Americans may particularly benefit from regular health screenings, targeted sleep interventions, and enhanced acculturation and physical performance. These interventions should be implemented through a culturally sensitive, community-based approach to ensure effectiveness and accessibility. By addressing sleep-related factors in cognitive health promotion efforts, researchers and practitioners can work towards reducing disparities and improving overall well-being among older adults, particularly within minority communities.

Abbreviations

PINE	Population Study of Chinese Elderly in Chicago
C_MMSE	Chinese Mini-Mental State Examination
PSQI	Pittsburgh Sleep Quality Index
BMI	Body mass index
IADL	Instrumental Activities of Daily Living

Supplementary Information

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Supplementary Material 1

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Author contributions

F. T. designed the study, supervised data analysis, and wrote the paper. Y. Z. and D. J. drafted methods section and made tables. G. J. searched the literature and completed the reference. Y. J. assisted in designing and editing the paper. All authors reviewed the paper.

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Data availability

The data are available upon request to Dr. Yanping Jiang (yanping.jiang@ifh.rutgers.edu) Restrictions may apply.

Declarations

Ethics approval and consent to participate

Informed consent was obtained from all participants, and research protocols were previously approved by the Institutional Review Board at Rush University Medical Center in Chicago, Illinois (IRB 10090203). This secondary analysis study has been approved by Institutional Review Boards at the University of Pittsburgh (IRB EXT20030031) and Rutgers, The State University of New Jersey (IRB Pro2018001578).

Consent for publication

Not relevant to this study.

Competing interests

The authors declare no competing interests.

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References

1. McSorley VE, Bin YS, Lauderdale DS. Associations of sleep characteristics with cognitive function and decline among older adults. Am J Epidemiol. 2019;188:1066–75.
2. Sindi S, Johansson L, Skoog J, Mattsson AD, Sjöberg L, Wang HX, et al. Sleep disturbances and later cognitive status: a multi-centre study. Sleep Med. 2018;52:26–33.
3. Chen R, Wang J, Pederson AM, Prather AA, Hirst AK, Ackley S, et al. Evaluation of racial and ethnic heterogeneity in the associations of sleep quality and sleep apnea risk with cognitive function and cognitive decline. Alzheimer's Dement. 2024. https://doi.org/10.1002/trc2.12441.
4. George KM, Peterson RL, Gilsanz P, Mungas DM, Glymour MM, Mayeda ER, Whitmer RA. Racial/ethnic differences in sleep quality among older adults: Kaiser Healthy Aging and Diverse Life experiences (KHANDLE) study. Ethn Dis. 2020. https://doi.org/10.18865/ed.30.3.469.
5. Kaufmann CN, Mojtabai R, Hock RS, Thorpe RJ Jr, Canham SL, Chen LY, et al. Racial/ethnic differences in insomnia trajectories among US older adults. Am J Geriatri Psychiatry. 2016. https://doi.org/10.1016/j.jagp.2016.02.049.
6. Yaffe K, Falvey CM, Hoang T. Connections between sleep and cognition in older adults. Lancet Neurol. 2014. https://doi.org/10.1016/S1474-4422(14)70172-3.
7. Miner B, Kryger MH. Sleep in the aging population. Sleep Med Clin. 2017;12:31–8.
8. Qin S, Leong R, Ong JL, Tang J, Chee M. Associations between objectively measured sleep parameters and cognition in healthy older adults: a meta-analysis. Sleep Med Rev. 2023; 67.
9. Brewster GS, Varrasse M, Rowe M. Sleep and cognition in community-dwelling older adults: a review of literature. Healthcare. 2015;3:1243–70.
10. Scullin MK, Bliwise DL. Sleep, cognition, and normal aging: integrating a half century of multidisciplinary research. Perspect Psychol Sci. 2015;10:97–137.
11. Alegría M, Álvarez K, DiMarzio K. Immigration and mental health. Curr Epidemiol Rep. 2017;4:145–55.
12. Leong RLF, Chee MWL. Understanding the need for sleep to improve cognition. Annu Rev Psychol. 2023;74:27–57.
13. Zhan J, Yang K, Sun Z, Bai L, Lu X, Wang X, et al. The sleep quality of the frontline healthcare workers and the improving effect of Tai Chi. Front Psychiatry. 2022. https://doi.org/10.3389/fpsyt.2022.883590.
14. Liu X, Yan G, Bullock L, Barksdale DJ, Logan JG. An examination of psychological stress, fatigue, sleep, and physical activity in Chinese americans. J Immigr Mino Health. 2023;25:168–75.
15. Budiman A, Ruiz NG. Key facts about Asian Americans, a diverse and growing population. 2021. https://www.pewresearch.org/fact-tank/2021/04/29/key-facts-about-asian-americans/. Accessed December 3, 2024.
16. Chen X, Wang R, Zee P, Lutsey PL, Javaheri S, Alcántara C, et al. Racial/ethnic differences in sleep disturbances: the multi-ethnic study of atherosclerosis (MESA). Sleep. 2015;38:877–88.
17. Wei M, Shi J, Li T, et al. Diagnostic accuracy of the Chinese version of the trail-making test for screening cognitive impairment. Am J Geriatr Psychiatry. 2018;66:92–9.
18. Chow TW, Ross L, Fox P, et al. Utilization of Alzheimer's disease community resources by asian-americans in California. Int J Geriatr Psychiatry. 2010;15:838–47.
19. Tang F, Chi I, Dong X. Sex differences in the prevalence and incidence of Cognitive Impairmen t: does Immigration Matter? J Am Geriatr Soc. 2019;67(S3):S513–18.
20. Song Y, Ryan GW, Lee D, Kim H, Martin JL, Kramer BJ, et al. Experiences of sleep problems among older Korean immigrants. Res Gerontol Nurs. 2022;15:193–202.
21. Dong X, Wong E, Simon MA. Study design and implementation of the PINE study. J Aging Health. 2014;26(Suppl):1085–99.
22. Smith A. Symbol Digit modalities Test (SDMT). Manual (revised). Los Angeles: Western Psychological Services; 1982.
23. Albert M, Smith LA, Scherr PA. Use of brief cognitive tests to identify individuals in the community with clinically diagnosed Alzheimer's disease. Int J Neurosci. 1991;57:167–78.
24. Wechsler D. WMS-R: Wechsler Memory Scale-Revised: Manual. San Antonio, TX: Psychological Corp; 1987.
25. Chiu HF, Lee HC, Chung WS, Kwong PK. Reliability and validity of the cantonese version of Mini-mental State Examination. East Asian Archives Psychiatry. 1994;4:25–8.
26. Li LW, Ding D, Wu B, Dong X. Change of cognitive function in US Chinese older adults: a population-based study. J Gerontol Biol Sci Med Sci. 2017;72(Suppl):S5–10.
27. Buysse DJ, Reynolds CF III, 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.
28. Fabbri M, Beracci A, Martoni M, Meneo D, Tonetti L, Natale V. Measuring subjective sleep quality: a review. Int J Environ Res Public Health. 2021;18:1082.
29. Mollayeva T, Thurairajah P, Burton K, Mollayeva S, Shapiro CM, Colantonio A. The Pittsburgh sleep quality index as a screening tool for sleep dysfunction in clinical and non-clinical samples: a systematic review and meta-analysis. Sleep Med Rev. 2016;25:52–73.
30. Zhang C, Zhang H, Zhao M, Li Z, Cook CE, Buysse DJ, et al. Reliability, validity, and factor structure of Pittsburgh Sleep Quality Index in community-based centenarians. Front Psychiatry. 2020. https://doi.org/10.3389/fpsyt.2020.573530.
31. Zhang HS, Li Y, Mo HY, Qiu DX, Zhao J, Luo JL, et al. A community-based cross-sectional study of sleep quality in middle-aged and older adults. Qual Life Res. 2017;26:923–33.
32. Levine DW, Lewis MA, Bowen DJ, Kripke DF, Kaplan RM, Naughton MJ, Shumaker SA. Reliability and validity of women's Health Initiative Insomnia Rating Scale. Psychol Assess. 2003;15:137–48.
33. Sands-Lincoln M, Loucks EB, Lu B, Carskadon MA, Sharkey K, Stefanick ML, et al. Sleep duration, insomnia, and coronary heart disease among postmenopausal women in the women's Health Initiative. J Womens Health. 2013;22:177–86.
34. Marin G, Sabogal F, Marin BV, Otero-Sabogal R, Perez-Stable EJ. Development of a short acculturation scale for hispanics. Hispanic J Behav Sci. 1987;9:183–205.
35. Nagi SZ. (1976). An epidemiology of disability among adults in the United States. The Milbank Mem Fund Q Health Soc. 1976; 54:439 – 67.
36. Ng CD. Stratification of BMI categories among older adults within and across countries. Public Health Nutr. 2020;23:254–63.
37. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med. 2001;16:606–13.
38. Lawton MP, Brody EM. Assessment of Older people: self-maintaining and instrumental activities of Daily Living. Gerontologist. 1969;9:179–86.
39. Seltman HJ, Experimental design. and analysis. 2018. https://web.archive.org/web/20180720062852id_/http://www.stat.cmu.edu/~hseltman/309/Book/Book.pdf. Accessed 15 Jan 2020.
40. StataCorp. Stata Statistical Software: Release 18. College Station. TX: StataCorp LLC; 2023.
41. Nebes RD, Buysse DJ, Halligan EM, Houck PR, Monk TH. Self-reported sleep quality predicts poor cognitive performance in healthy older adults. J Gerontol B Psycholo Sci Soc Sci. 2009;64B:180–7.
42. della Monica C, Johnsen S, Atzori G, Groeger JA, Dijk D-J. Rapid Eye Movement Sleep, Sleep continuity and slow Wave Sleep as predictors of Cognition, Mood, and subjective sleep quality in healthy men and women, aged 20–84 years. Front Psychiatry. 2018;9:255.
43. Júnior FWNH, de Almondes KM. Sleep and executive functions in older adults: a systematic review. Dement Neuropsychol. 2016;10:185–97.
44. Keil SA, Schindler AG, Wang MX, Piantino J, Silbert LC, Elliott JE, et al. Longitudinal sleep patterns and cognitive impairment in older adults. JAMA Netw Open. 2023. https://doi.org/10.1001/jamanetworkopen.2023.46006.
45. Suh SW, Han JW, Lee JR, Byun S, Kwon SJ, Oh SH, et al. Sleep and cognitive decline: a prospective nondemented elderly cohort study. Ann Neurol. 2018;83:472–82.
46. Suh SW, Han JW, Lee JR, et al. Sleep and cognitive decline: a prospective nondemented elderly cohort study. Ann Neurol. 2018;83:472–82.
47. Nakakubo S, Doi T, Makizako H, et al. Sleep condition and cognitive decline in Japanese community-dwelling older people: data from a 4-year longitudinal study. J Sleep Res. 2019;28:e12803.
48. Gildner TE, Salinas-Rodriguez A, Manrique-Espinoza B, et al. Does poor sleep impair cognition during aging? Longitudinal associations between changes in sleep duration and cognitive performance among older Mexican adults. Arch Gerontol Geriatr. 2019;83:161–8.

49. Landry GJ, Best JR, Liu-Ambrose T. Measuring sleep quality in older adults: a comparison using subjective and objective methods. Front Aging Neurosci. 2015. https://doi.org/10.3389/fnagi.2015.00166.

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