JCSM
Journal of Clinical Sleep Medicine

http://dx.doi.org/10.5664/jcsm.3782

Associations between Sleep Duration, Sleep Quality, and Cognitive Test Performance among Older Adults from Six Middle Income Countries: Results from the Study on Global Ageing and Adult Health (SAGE)

Theresa E. Gildner, M.S.[1]; Melissa A. Liebert, M.S.[1]; Paul Kowal, Pharm.D.[2,3]; Somnath Chatterji, M.D.[2]; J. Josh Snodgrass, Ph.D.[1]

[1]*Department of Anthropology, University of Oregon, Eugene, OR;* [2]*World Health Organization, Geneva, Switzerland;* [3]*University of Newcastle Research Centre on Gender, Health, and Ageing, Newcastle, NSW, Australia*

SCIENTIFIC INVESTIGATIONS

Background*:* Alterations in sleep architecture are common among older adults. Previous studies have documented associations between sleep duration, sleep quality, and cognitive performance in older individuals, yet few studies have examined these trends using population-based samples from non-Western societies. The present cross-sectional study uses nationally representative datasets from six countries to test several hypotheses related to sleep patterns and cognitive function.

Methods: Data were drawn from the first wave of the World Health Organization's study on global ageing and adult health (SAGE), a longitudinal study using samples of older adults (≥ 50 years old) in 6 middle-income countries (China, Ghana, India, Russian Federation, South Africa, and Mexico). Self-report data provided information on sleep quality and sleep duration over the previous 2 nights, and 5 cognitive tests (immediate and delayed verbal recall, forward and backward digit span, and verbal fluency) were used to create a composite z-score of cognitive performance.

Results: Individuals with intermediate sleep durations (> 6-9 h/night) exhibited significantly higher cognitive scores than individuals with short sleep (0-6 h/night; $p < 0.001$) or long sleep duration (> 9 h/night; $p < 0.001$). Self-reported sleep quality was positively correlated with cognitive z-score ($p < 0.05$). Significant sex differences were observed; men generally had higher sleep quality and cognitive scores, while women reported longer sleep durations.

Discussion: This study documented positive correlations between cognitive scores and sleep quality, and between cognitive z-scores and intermediate sleep duration. These findings are clinically important given the growing rates of dementia and aging populations globally.

Keywords: cognitive function, aging, sleep duration, sleep quality, dementia

Citation: Gildner TE, Liebert MA, Kowal P, Chatterji S, Snodgrass JJ. Associations between sleep duration, sleep quality, and cognitive test performance among older adults from six middle income countries: results from the study on global ageing and adult health (SAGE). *J Clin Sleep Med* 2014;10(6):613-621.

Detrimental changes in sleep duration and quality are more common with increasing age.[1,2] These alterations include a phase advance in circadian rhythms, thought to be the result of deterioration in the suprachiasmatic nuclei region of the brain.[1] Older adults also report an increased occurrence of sleep disorders associated with disrupted and fragmented sleep patterns. These conditions often reduce slow wave sleep (SWS) and REM sleep, the deepest and most restorative sleep stages. Disruption to SWS and REM sleep can lead to increased daytime sleepiness and a decreased ability to handle stress.[2]

Age-related changes in sleep may contribute to cognitive decline among older individuals, yet this issue has not been extensively studied. Both short and long sleep duration have been linked to reduced cognitive performance.[3,4] Sleep deprivation dulls the senses, slows reaction times, and impedes memory formation.[3] Conversely, long sleep duration may reflect poor sleep quality or disturbed sleep patterns, which may impair cognitive performance.[4] Furthermore, studies on sleep quality in older adults indicate that the impairment of normal sleep structure may detrimentally affect cognitive function.[5] Reports of chronic problems with sleep latency (time to sleep onset) and maintenance are often associated with adverse consequences, including drowsiness and reduced performance on cognitive tests.[5] Unfortunately, research to date has largely been limited to high income countries and has typically relied on data from small and non-representative samples.

BRIEF SUMMARY

Current Knowledge/Study Rationale: Few studies have assessed the contribution of sleep quality and quantity to cognitive performance in older adults, especially in non-Western populations. A comprehensive understanding of all factors influencing mental acuity is essential in the design of disease-modifying therapies.

Study Impact: This study evaluated associations between measures of sleep and cognitive performance using large nationally representative samples of older adults drawn from six middle-income countries, providing a unique examination of this relationship. Enhanced cognitive functioning was significantly associated with intermediate sleep duration and higher sleep quality, suggesting that sleep measures may influence cognitive performance in older individuals from different countries.

Sociodemographic and lifestyle factors also appear to strongly influence sleep patterns.[6-9] Notably, low socioeconomic status (SES) and poor living conditions have been linked with reduced self-reported sleep quality, increased sleep latency, and increased time awake after sleep onset in American, British, and Finnish cohorts.[7-9] Factors that may be more common as a result of low SES (e.g., noise pollution, light exposure, uncomfortable sleeping surfaces, lack of temperature control, occupational stress) may result in deficient sleep patterns.[7-9] Sex differences also appear to influence sleep and cognitive test performance in older individuals, with women reporting more sleep onset and maintenance problems than men.[10] Cultural differences also influence sex differences in cognitive performance. Specifically, women in many countries receive less schooling than men, likely contributing to observed differences in cognitive test performance.[4] Cross-cultural studies in this area are needed to assess the extent to which these changes represent global patterns or those strongly influenced by cultural and environmental conditions. This information is critical since the development of effective dementia treatments and the ability to minimize age-related cognitive changes are dependent on the identification of key contributing factors to cognitive decline. These clinical interventions have important implications toward addressing the global burden of dementia.

Despite considerable research, questions remain about the link between sleep patterns and cognitive performance. Although a clear relationship between sleep and cognitive decline has been demonstrated, it is difficult to determine which factor precedes the other. Nonetheless, identifying sleep disorders in older adults is critical since they may have implications for cognition.[11,12] Treatments can then be directed to addressing both sleep problems and cognitive decline simultaneously.

The present study examines links between sleep patterns and cognitive test performance using data from the first wave of the World Health Organization's study on global ageing and adult health (SAGE).[13] Data from six middle income countries (China, Ghana, India, Mexico, the Russian Federation, and South Africa) are utilized to construct a more comprehensive picture of how sleep architecture and cognitive performance among older adults varies across these countries. Four hypotheses were tested: (1) age would be inversely correlated with cognitive scores; (2) short and long sleep duration would be significantly associated with poor cognitive test performance; (3) good sleep quality would be positively correlated with cognitive scores; and (4) women would report poorer sleep quality and longer sleep duration than men, and these tendencies would be correlated with reduced performance on cognitive tests.

METHODS

Study Design and Participants

Nationally representative samples of older adults (≥ 50 years old) and comparative samples of younger adults (18-49 years old) were drawn from each SAGE country.[13] Sampling in each country was based on a stratified multistage cluster sample design. Strata were uniquely defined for each country to ensure the full range of living conditions in that nation was represented in the study. In China, strata were defined by eight provinces and two localities (urban or rural), resulting in 16 total strata. In Ghana, the sample was stratified by 10 administrative regions and two types of locality (urban or rural), resulting in 20 total strata. The Indian strata were defined by six states and two localities (urban or rural), resulting in 12 total strata. The South African sample was stratified by nine providences, two localities (urban or rural), and predominant race/ethnic group ("African/Black," "White," "Colored," and "Indian/Asian"); not all combinations of stratification variables were possible, resulting in 50 total strata. The Russian Federation sample was stratified by the seven federal districts. Finally, in Mexico, strata were defined by three localities: rural (< 25,000 inhabitants), urban (< 100,000 and > 2,499 inhabitants), or metropolitan (> 99,999 inhabitants). Analyses in the present study primarily focused on older adults. Younger individuals (< 50 years old) were excluded from the analyses, except in a comparison between older and younger (< 50 years old) participants for average cognitive function score by sex. Face-to-face interviews were used to collect household and individual level data.[13]

Ethical Approval

SAGE was approved by the World Health Organization's Ethical Review Committee. Additionally, each partner organization implementing SAGE obtained ethical clearance through their respective institutional review bodies. Informed consent was obtained from all study participants.

Independent Variables

Age, sex, and highest level of education completed were collected. Age reporting overall was quite good across all countries. The United Nations International Standard Classification of Education 1997 (ISCED 97) scheme was used to harmonize education levels across countries.[14]

Sleep Variables

Participants were asked their sleep duration on each of the preceding two nights and then asked to rate their sleep quality on a scale of 1 to 5 (1 = very good quality, 5 = very poor quality) for each night; these measures did not include daytime sleep. These results were then reverse coded, so that a higher rating corresponded with good quality sleep and a lower rating represented poor quality sleep. In accordance with other sleep studies, the duration values across two nights were averaged together to create a summary measure of sleep length, so that mean sleep durations could be compared.[4,15] Similarly, the quality values were also averaged together to compute the sleep quality typical for each individual. Following a standard approach,[4,16,17] individuals in the six countries combined were divided into three sleep duration categories: short sleep (0-6 h), intermediate sleep (> 6-9 h), and long sleep (> 9 h). The total pooled sample was also sorted into three generated average sleep quality categories: low sleep quality (average rating of 1-2); intermediate sleep quality (average rating of 2.5-3.5), and high sleep quality (average rating of 4-5).

Cognition Variables

Five cognitive performance tests were used to create a summary variable of cognitive function for each participant. These tests included immediate and delayed verbal recall, forward and backward digit span, and verbal fluency. For the immediate verbal recall test, interviewers first read a list of 10 words aloud and asked the participants to immediately recall as many words as they could in one minute. Three trials of this test were performed. Following the third trial, the interviewer administered the other cognitive tests, after which delayed recall ability was assessed by asking participants to recall the list of words. The digit span tests required participants to repeat back progressively longer series of numbers, with the total score the longest digit span repeated without error. This process was then performed with the respondent repeating new sets of progressively longer digit spans in reverse (backwards). The verbal fluency test consisted of naming as many animals as possible in one minute. The final score was correct responses minus errors. In accordance with other cognitive studies, composite z-scores were calculated to facilitate the comparison of cognitive test performance between individuals.[18,19] Z-scores for each cognitive test were first computed; these five z-scores were then summed for each individual, resulting in a final composite z-score.

Statistical Analyses

Tests for normality were performed, and no violations were observed. Parametric tests were subsequently conducted using SPSS version 20 to test the hypotheses; statistically significant results were those with $p < 0.05$.

Examination of Country and Sex Differences

Mean sleep duration, quality, and cognitive performance scores were calculated for males and females in each population. Three factorial ANOVAs were used to test if cognitive test performance, sleep duration, and sleep quality varied by sex and population. Simple effects analyses (with a Bonferroni adjustment) were utilized to compare males and females within and between countries on average cognitive, sleep duration, and sleep quality scores.

Contribution of Age, Education Level, Sleep Quality, and Sleep Duration to Cognitive Test Score Variation

A series of linear regressions were conducted to test the hypotheses and evaluate the relative contribution of age and sleep patterns to cognitive score variation, while controlling for education level. Education level was included as dummy codes in first step of the linear regression analyses to control for the contribution of education on variation in cognitive test performance.

Hypothesis One: The first linear regression estimated the relative association of age on cognitive z-scores. Participants from all countries were pooled and divided into younger individuals (18-49 years old) and older individuals (≥ 50 years old). These two groups were coded into a dichotomous variable (younger = 1, older = 2), which was entered in the second step of the regression, and sex was entered in the third step. A second linear regression was performed to determine if categories of age by decade (50-59; 60-69; 70-79; 80+ years old) contributed significantly to the model. This variable was dummy coded using the youngest age set (50-59 years old) as the reference group and entered in the second step of the regression, while sex was entered in the third step.

Hypothesis Two: A third linear regression examined if average sleep duration categories contributed to variation in cognitive test performance among older adults. Because intermediate sleep was expected to be associated with higher cognitive z-scores, these categories were dummy coded using intermediate sleep duration as the reference group and entered in the second step of the regression.

Hypothesis Three: Similarly, a fourth linear regression was conducted to estimate the relative contribution of sleep quality categories to cognitive score variation. The sleep quality categories were dummy coded and entered in the second step of the regression; because cognitive scores were expected to increase as sleep quality improved, low sleep quality served as the reference group.

Hypothesis Four: A final linear regression was conducted to examine the relative association of country, sex, the interaction between country and sex to cognitive z-scores. The six country categories were dummy coded using China as the reference group (because this country had the highest z-scores for the set of cognitive tests used in the present study). The country dummy codes were entered in the second step of the regression, sex in the third step, and the interactions between sex and each country dummy code were entered in the fourth step.

Examination of Relationship between Sleep Duration and Sleep Quality

Spearman correlations (ρ) were used to assess the association between average sleep duration and sleep quality. All correlations were conducted separately for men and women by country.

RESULTS

Descriptive statistics are presented in **Table 1**. The total mean composite cognition z-scores (sexes combined, n = 34,203) ranged from -1.88 in India to 0.93 in China. With the exception of Russia and Mexico, a significant sex difference was observed; average composite z-scores were significantly lower for women than men ($p < 0.001$). Mean sleep duration (sexes combined, n = 32,142) ranged from 7.1 h/night in India to 8.6 h/night in South Africa. Women in all countries reported longer average sleep duration than men ($p < 0.001$); these differences were significant in all countries except Russia and Mexico. Average subjective sleep quality ratings (sexes combined, n = 35,552) ranged from 3.3 in Russia to 4.0 in Mexico. In each country the average sleep quality rating was significantly lower for women than men ($p < 0.05$)

Cognitive Test Performance by Country and Sex

Country ($p < 0.001$) and sex ($p < 0.001$) had strong main effects on cognitive test performance in the present study. A significant interaction ($p < 0.001$) was also apparent between country and sex. Pairwise comparisons with a Bonferroni adjustment indicated that cognition z-scores differed significantly for each country pair ($p < 0.001$) except between China and Russia (D = 0.10, p = 1.00). A comparison of mean composite cognition scores between sexes indicated that men exhibit significantly higher scores compared to women in all countries ($p < 0.001$), except Russia (D = 0.20, p = 0.09) and Mexico (D = 0.12, p = 0.22; **Table 1**).

Table 1—Mean cognition z-scores, sleep duration (h/night), and subjective sleep quality for men, women, and sexes combined in each country with sample size (n).

	Composite Cognitive Score	Sleep Duration (h/night)	Subjective Sleep Quality
China Total	0.93 (n = 12,518)	7.56 (n = 12,794)	3.51 (n = 12,887)
Men	1.30 (n = 5,839)	7.62 (n = 6,009)	3.61 (n = 6,040)
Women	0.61 (n = 6,679)	7.51 (n = 6,785)	3.42 (n = 6,847)
Mean Sex Difference	0.69 ***	-0.11 ***	0.19 ***
Ghana Total	-0.60 (n = 4,114)	7.73 (n = 3,679)	3.87 (n = 4,276)
Men	0.08 (n = 2,168)	7.53 (n = 1,938)	3.90 (n = 2,233)
Women	-1.36 (n = 1,946)	7.95 (n = 1,741)	3.84 (n = 2,043)
Mean Sex Difference	1.44 ***	-0.42 ***	0.07 **
India Total	-1.88 (n = 6,291)	7.11 (n = 6,526)	3.63 (n = 6,551)
Men	-1.16 (n = 3,212)	6.98 (n = 3,285)	3.71 (n = 3,298)
Women	-2.64 (n = 3,079)	7.24 (n = 3,241)	3.54 (n = 3,253)
Mean Sex Difference	1.48 ***	-0.26 ***	0.17 ***
South Africa Total	-0.15 (n = 3,544)	8.58 (n = 3,507)	3.84 (n = 3,617)
Men	0.29 (n = 1,500)	8.48 (n = 1,492)	3.87 (n = 1,530)
Women	-0.47 (n = 2,044)	8.66 (n = 2,015)	3.81 (n = 2,087)
Mean Sex Difference	0.76 ***	-0.18 ***	0.06 *
Russia Total	0.82 (n = 3,374)	7.59 (n = 3,506)	3.28 (n = 3,813)
Men	0.95 (n = 1,190)	7.59 (n = 1,241)	3.43 (n = 1,354)
Women	0.75 (n = 2,184)	7.59 (n = 2,265)	3.20 (n = 2,459)
Mean Sex Difference	0.20	-0.01	0.24 ***
Mexico Total	-0.90 (n = 4,362)	7.66 (n = 2,130)	3.98 (n = 4,408)
Men	-0.82 (n = 1,698)	7.59 (n = 843)	4.00 (n = 1,744)
Women	-0.95 (n = 2,664)	7.71 (n = 1,287)	3.96 (n = 2,664)
Mean Sex Difference	0.12	-0.12	0.05 *

The number of asterisks indicates the level of significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) in the factorial ANOVA.

Table 2—Pairwise comparisons of the difference in average sleep duration (h/night) for each country pair (separated by sex).

	China	Ghana	India	South Africa	Russia	Mexico
Males						
China	–	0.09*	0.64***	-0.86***	0.03	0.03
Ghana	-0.09*	–	0.55***	-0.95***	-0.06	-0.06
India	-0.64***	-0.55***	–	-1.50***	-0.61***	-0.62***
South Africa	0.86***	0.95***	1.50***	–	0.89***	0.89***
Russia	-0.03	0.06	0.61***	-0.89***	–	-0.004
Mexico	-0.03	0.06	0.62***	-0.89*	0.00	–
Females						
China	–	-0.44***	0.27***	-1.15***	-0.09*	-0.20***
Ghana	0.44***	–	0.71***	-0.71***	0.35***	0.24***
India	-0.27***	-0.71***	–	-1.42***	-0.36***	-0.47***
South Africa	1.16***	0.71***	1.42***	–	1.07***	0.95***
Russia	0.09*	-0.35***	0.36***	-1.07***	–	-0.11*
Mexico	0.20***	-0.24***	0.47***	-0.95***	0.11*	–

Comparisons are statistically significant at: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Each value represents the difference between the country in the column and the country listed in row at the top of the table.

Sleep Duration by Country and Sex

Country ($p < 0.001$) and sex ($p < 0.001$) had strong main effects on sleep duration. A significant interaction ($p < 0.001$) was also identified between country and sex. Women reported significantly higher mean sleep duration than men ($p < 0.001$) in all countries except in Russia (D = -0.01, $p = 0.89$) and Mexico (D = -0.12, $p = 0.08$; **Table 1**). Men and women in South Africa reported longer sleep duration compared to all other countries ($p < 0.001$). Conversely, men and women in India reported lower sleep duration compared to all other countries ($p < 0.001$; **Table 2**). Mean female sleep durations between countries were all significant ($p < 0.05$; **Table 2**).

Sleep Quality by Country and Sex

Country ($p < 0.001$) and sex ($p < 0.001$) had strong main effects on sleep quality. A significant interaction ($p < 0.001$)

Table 3—Pairwise comparisons of the difference in average sleep quality rating for each country pair (separated by sex).

	China	Ghana	India	South Africa	Russia	Mexico
Males						
China	–	-0.29 **	-0.10 ***	-0.27 ***	0.18 ***	-0.40 ***
Ghana	0.29 ***	–	0.19 ***	0.03	0.47 ***	-0.10 ***
India	0.10 ***	-0.19 ***	–	-0.17 ***	0.28 ***	-0.30 ***
South Africa	0.27 ***	-0.03	0.17 ***	–	0.44 ***	-0.13 ***
Russia	-0.18 ***	-0.47 ***	-0.28 ***	-0.44 ***	–	-0.57 ***
Mexico	0.40 ***	0.10 ***	0.30 ***	0.13 ***	0.57 ***	–
Females						
China	–	-0.41 ***	-0.12 ***	-0.39 ***	0.23 ***	-0.53 ***
Ghana	0.41 ***	–	0.29 ***	0.02	0.64 ***	-0.12 ***
India	0.12 ***	-0.29 ***	–	-0.27 ***	0.35 ***	-0.41 ***
South Africa	0.39 ***	-0.02	0.27 ***	–	0.62 ***	-0.15 ***
Russia	-0.23 ***	-0.64 ***	-0.35 ***	-0.62 ***	–	-0.76 ***
Mexico	0.53 ***	0.12 ***	0.41 ***	0.15 ***	0.76 ***	–

Comparisons are statistically significant at: * p < 0.05, ** p < 0.01, *** p < 0.001. Each value represents the difference between the country in the column and the country listed in row at the top of the table.

was also observed between country and sex. Men reported significantly higher sleep quality scores than women in all countries ($p < 0.05$) (**Table 1**). Men and women in Mexico reported significantly higher sleep quality values compared to all other countries ($p < 0.001$) (**Table 3**).

Age and Cognitive Test Performance

The results of the linear regression examining the contribution of age to variation in cognitive test performance indicated that education level explained a significant amount of the variance in cognitive scores ($R^2 = 0.127$, $p < 0.001$). Increasing education relative to the lowest schooling category was associated with linear advances in cognitive test performance, highest at "completed college/university" and then slightly lower for "completed post-grad degree." Adding the dichotomous younger/older age variable explained a significant amount of additional variance (R^2 change = 0.013, $p < 0.001$). Older individuals ($p < 0.001$) exhibited lower cognitive test scores than their younger counterparts. Adding sex to the model explained a marginal amount of additional variance (R^2 change < 0.001, $p < 0.001$); this very small but statistically significant finding is likely due to the large sample size. Women exhibited lower cognitive scores relative to men on this battery of cognitive tests ($p < 0.001$; **Table 5**).

The results of a second linear regression examining the contribution of age categories by decade to composite cognitive z-scores indicated that education level explained a significant 10.6% of the variance in cognitive scores ($R^2 = 0.106$, $p < 0.001$). Increasing education relative to the lowest schooling category was associated with linear advances in cognitive scores, highest at "completed college/university" and then slightly lower for "completed post-grad degree." Adding the age by decade dummy codes explained a significant amount of additional variance (R^2 change = 0.072, $p < 0.001$). Cognitive test performance decreased linearly across age groups, in which individuals aged 60-69, 70-79, and 80+ years exhibited lower cognitive scores than their younger (50-59 year old) counterparts ($p < 0.001$; **Table 5**). Adding sex to the model explained a nonsignificant amount of variance (R^2 change = 0.000, $p = 0.145$).

Table 4—Spearman correlation coefficients of sleep duration and sleep quality for each country (separated by sex).

	Men	Women
China	0.32 ***	0.32 ***
Ghana	0.30 ***	0.18 ***
India	0.19 ***	0.25 ***
Mexico	0.29 ***	0.24 ***
Russia	0.10 ***	0.28 ***
South Africa	0.16 ***	0.18 ***

*** p < 0.001.

Sleep Patterns and Cognitive Test Performance

A third linear regression was used to assess the contribution of sleep duration to cognitive score variation while controlling for education. Education level explained a significant amount of the variance in cognitive scores ($R^2 = 0.101$, $p < 0.001$). Linear advances in cognitive scores were evident as education level increased, peaking at "completed college/university" and then decreasing slightly for "completed post-grad degree." Adding sleep duration explained a significant amount of additional variance (R^2 change = 0.005, $p < 0.001$). Short sleepers (< 6 h) exhibited significantly lower cognitive scores ($p < 0.001$) than intermediate sleepers (> 6-9 h). Similarly, long sleepers (> 9 h) displayed significantly lower cognitive test performance ($p < 0.001$) than intermediate sleepers (see **Table 5**).

Significant differences were also observed in the linear regression examining cognitive performance between the sleep quality categories. Education level explained a significant amount of the variance in cognitive scores (R^2 change = 0.106, $p < 0.001$). Increasing education relative to the lowest schooling category was associated with linear advances in cognitive scores, peaking at "completed college/university" and then decreasing slightly for "completed post-grad degree." Adding sleep quality explains a significant amount of additional variance (R^2 change = 0.007, $p < 0.001$). When compared to low quality sleepers (rating of 1-2), cognitive test performance

Table 5—Multiple regression models for prediction of cognitive scores (sexes and populations combined).

Variable	Coefficients (SE)	β	p	Model r^2 / p
Composite Cognitive Z-score				0.14 / < 0.001***
Constant	1.464 (0.112)		< 0.001	
Education Level: Less than primary vs. completed primary	0.827 (0.052)	0.107	< 0.001	
Less than primary vs. completed secondary	1.840 (0.054)	0.229	< 0.001	
Less than primary vs. completed high school	2.475 (0.053)	0.309	< 0.001	
Less than primary vs. completed college/university	3.600 (0.070)	0.310	< 0.001	
Less than primary vs. completed post-grad	3.080 (0.185)	0.091	< 0.001	
Young-Old Category	-0.940 (0.044)	-0.117	< 0.001	
Sex	-0.139 (0.036)	-0.021	< 0.001	
Composite Cognitive Z-score				0.18 / < 0.001***
Constant	0.330 (0.045)		< 0.001	
Education Level: Less than primary vs. completed primary	0.723 (0.054)	0.096	< 0.001	
Less than primary vs. completed secondary	1.557 (0.058)	0.192	< 0.001	
Less than primary vs. completed high school	2.027 (0.057)	0.253	< 0.001	
Less than primary vs. completed college/university	3.166 (0.076)	0.271	< 0.001	
Less than primary vs. completed post-grad	2.837 (0.215)	0.079	< 0.001	
Age Category: 50-59 vs. 60-69	-0.749 (0.045)	-0.108	< 0.001	
50-59 vs. 70-79	-1.825 (0.054)	-0.218	< 0.001	
50-59 vs. 80+	-3.197 (0.089)	-0.219	< 0.001	
Composite Cognitive Z-score				0.11 / < 0.001***
Constant	-0.243 (0.045)		< 0.001	
Education Level: Less than primary vs. completed primary	0.747 (0.060)	0.099	< 0.001	
Less than primary vs. completed secondary	1.683 (0.063)	0.212	< 0.001	
Less than primary vs. completed high school	2.190 (0.062)	0.280	< 0.001	
Less than primary vs. completed college/university	3.227 (0.085)	0.277	< 0.001	
Less than primary vs. completed post-grad	2.813 (0.237)	0.078	< 0.001	
Sleep Duration Category: Intermediate vs. short	-0.367 (0.056)	-0.044	< 0.001	
Intermediate vs. long	-0.657 (0.070)	-0.062	< 0.001	
Composite Cognitive Z-score				0.11 / < 0.001***
Constant	-1.165 (0.086)		< 0.001	
Education Level: Less than primary vs. completed primary	0.874 (0.056)	0.116	< 0.001	
Less than primary vs. completed secondary	1.881 (0.060)	0.232	< 0.001	
Less than primary vs. completed high school	2.385 (0.059)	0.297	< 0.001	
Less than primary vs. completed college/university	3.313 (0.079)	0.283	< 0.001	
Less than primary vs. completed post-grad	2.841 (0.224)	0.079	< 0.001	
Sleep Quality Category: Low vs. intermediate	0.295 (0.086)	0.043	0.001	
Low vs. high	0.792 (0.083)	0.120	< 0.001	
Composite Cognitive Z-score				0.18 / 0.038*
Constant	0.699 (0.125)		< 0.001	
Education Level: Less than primary vs. completed primary	0.554 (0.172)	0.073	0.001	
Less than primary vs. completed secondary	1.471 (0.181)	0.181	< 0.001	
Less than primary vs. completed high school	2.158 (0.180)	0.269	< 0.001	
Less than primary vs. completed college/university	3.147 (0.240)	0.270	< 0.001	
Less than primary vs. completed post-grad	4.332 (0.656)	0.120	< 0.001	
Country: China vs. Ghana	-1.414 (0.075)	-0.119	< 0.001	
China vs. India	-2.394 (0.061)	-0.251	< 0.001	
China vs. Mexico	-1.404 (0.061)	-0.152	< 0.001	
China vs. Russia	-1.135 (0.069)	-0.103	< 0.001	
China vs. South Africa	-2.058 (0.065)	-0.222	< 0.001	
Sex	-0.202 (0.076)	-0.031	0.008	
*Country*Sex Interaction*: China vs. Ghana	0.181 (0.108)	0.038	0.094	
China vs. India	0.159 (0.115)	0.031	0.167	
China vs. Mexico	0.325 (0.114)	0.064	0.004	
China vs. Russia	0.357 (0.152)	0.048	0.019	
China vs. South Africa	-0.404 (0.488)	-0.015	0.408	

Comparisons are statistically significant at: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Sex: 1 = male, 2 = female. Reference groups used in the creation of dummy codes for each categorical variable: educational levels = less that primary school; age by decade = 50-59 year olds; sleep duration = intermediate sleep (> 6-9 h); sleep quality = low sleep quality (average rating of 1-2); country = China.

increases linearly, in which individuals with intermediate and high sleep quality exhibited significantly higher cognitive z-scores ($p = 0.001$) than low quality sleepers (see **Table 5**). Spearman correlations indicated that average sleep duration and sleep quality were significantly positively correlated ($p < 0.001$) for both sexes in all countries (**Table 4**).

Country, Sex, and Cognitive Test Performance

A final linear regression was used to examine the effect of country and sex on cognitive test performance variation while controlling for schooling. Education level explained a significant amount of the variance in cognitive scores (R^2 change = 0.106, $p < 0.001$). Cognitive scores increased linearly as education level increased, peaking at "completed post-grad degree." Adding country explained a significant amount of additional variance (R^2 change = 0.078, $p < 0.001$), suggesting that there are significant country differences in test performance on the set of cognitive measures used. Adding sex to the model explained a nonsignificant amount of variance (R^2 change = 0.000, $p = 0.397$), indicating that sex does not significantly affect cognitive scores in this model. Adding the interaction between country and sex explained a marginal amount of additional variance (R^2 change < 0.0010, $p = 0.038$); this very small but statistically significant finding is likely due to the large sample size.

DISCUSSION

This study provides a unique examination of the associations between sleep quality, duration, and cognitive test performance in older individuals using an extensive and unparalleled collection of cross-cultural measurements. Previous studies examining these patterns have been confined to high income countries and have generally relied on data collected from small and non-representative population samples. The SAGE sample is unique in that it is very large, drawn from several diverse nations, and representative of the range of living conditions in each country. Furthermore, as it is a longitudinal study, factors affecting well-being during aging can be identified by analyzing health measures in the same individuals over time.

The present study found support for all four hypotheses. Short (0-6 h/night) and long (> 9 h/night) sleep durations were significantly associated with poorer cognitive test performance relative to intermediate sleep lengths (6.01-9 h/night). Higher average sleep quality scores (≥ 4) were significantly associated with increased cognitive test performance. Composite cognition z-scores were lower in older individuals. Sex differences were evident in all analyses, with women generally exhibiting significantly longer sleep durations (except in Russia and Mexico), lower sleep quality ratings, and lower composite cognition z-scores in the present study (except in Russia and Mexico) relative to their male counterparts in each country.

These results are consistent with previous findings from research examining smaller samples drawn from high income countries; these studies indicate that sleep deprivation negatively impacts cognitive performance as well as mood and motor function.[20,21] Sleep deprivation degrades the peak circadian drive for wakefulness over time and affects neural processing, resulting in the destabilization of the wake state and overall neurocognitive function. The negative impact of these neurocognitive effects are particularly evident in the prefrontal cortex, the area of the brain related to attention and working memory abilities.[20] A recent study has directly linked structural changes in prefrontal cortex with sleep-related memory problems.[22] In a study by Mander and colleagues, natural atrophy in the medial prefrontal cortex was observed in older adults; this area of the brain was roughly one-third smaller in older individuals than younger individuals. These changes are thought to reduce the amount of restorative SWS, thus inhibiting knowledge consolidation and memory formation.[22]

Previous studies have also found that long sleep duration may contribute to variation in cognitive test performance, as was observed in the present study.[4,21] Long sleep duration may simply reflect the presence of sleep disorders or other illnesses. These individuals may require more time in bed to feel rested and therefore report longer sleep durations. However, longer sleep duration may not completely compensate for underlying health conditions, and cognitive decline may still occur.

An important finding in the present study is the sex difference in all sleep and cognition variables. There are several possible reasons for these observed differences. First, older women typically report more sleep disturbances than older men, which in part is thought to be due to postmenopausal changes in hormone profile (for instance, estrogen deficiency) and increased bladder instability.[23] Second, longer sleep duration and poorer subjective sleep scores in women have also been associated with feelings of isolation, which can result from widowhood or a perceived lack of social support.[15] Third, poor cognitive scores in women may be due to suboptimal sleep patterns. However, lower scores on cognitive performance tests may also result from women receiving less schooling than their male counterparts.[4] The present study provides evidence of this idea and indicates that sex was not a significant predictor of cognitive z-scores beyond what was accounted for by education and country. This supports the idea that schooling and other cultural factors may play an important role in structuring these sex differences.

The large, nationally representative samples from six countries used in the present study provided an opportunity to examine the variation in sleep patterns and associations with cognition between countries. Significant differences in sleep duration and quality were observed between countries with different levels of economic development. The two African countries (South Africa and Ghana) exhibited the longest sleep durations and, together with Mexico, also reported the highest sleep quality scores compared to the other countries. This finding might be explained by differences in economic development (e.g., different work patterns and occupations, types of housing, and living arrangements) between these countries and the others included in the analyses. Sleep environment has been shown to affect sleep quality and duration; factors typically associated with a more urban lifestyle (such as, noise, light exposure, and non-private sleep quarters) often have a detrimental impact on sleep quality and quantity.[7-9] Social factors like financial stress, health worries, alcohol consumption, and an unfavorable work schedule (e.g., working the night shift) may also negatively affect sleep quality.[7-9] Environmental factors and economic infrastructure therefore play an important role in shaping sleep patterns. It is possible that individuals living in more rural areas are less exposed to these adverse social stressors and poor sleep environments, and subsequently report longer sleep durations and higher sleep quality scores.

Limitations

The present study has several important limitations. First, the battery of cognitive tests used was not developed in the countries studied. These tests only examined certain aspects of cognitive performance, but did not measure overall cognitive function. Furthermore, differences in composite z-scores were likely affected by cultural variation and extent of economic development, which structure differences in schooling. These dissimilarities may have resulted in specific populations obtaining higher tests scores simply due to the nature of cognitive measures utilized.

A second limitation is that the sleep data used were reliant on accurate participant responses in sleep duration, yet it is often difficult for individuals to discern between time in bed and time asleep. Studies have shown that when asked how many hours they slept, participants often report time spent in bed; however, this value may exceed time spent asleep.[24] Objective measures of sleep based on polysomnography or actigraphy would more accurately capture individual sleep patterns, including sleep duration, transitions between sleep states, and duration of night awakenings.[25] A third limitation is the reliance on data from only the two nights of sleep prior to the interview, which may not accurately capture typical sleep patterns.

Finally, because the data in the present study are cross-sectional, it is impossible to determine the causality between the variables assessed. It is possible that the cognitive decline observed may not be due to deficient sleep patterns; instead, cognitive decline in older individuals could result in suboptimal sleep duration and poor sleep quality. Longitudinal data following the progression of these trends over time is required to further parse out these interactions. SAGE is in the process of collecting the second wave of data on participants which will help address this issue. These data will also facilitate the examination of other issues such as undiagnosed illness, which could affect sleep and cognition variables, but would only emerge over time. However, given the association between sleep patterns and cognitive test performance, the diagnosis of sleep disorders in older adults is critical for the design and implementation of effective cognitive decline intervention programs.

CONCLUSION

In conclusion, this study documented relationships between sleep quality and quantity and cognitive test performance among older individuals from six middle income countries. These results confirm previous findings in Western populations and suggest that sleep patterns are associated with cognitive test performance cross-culturally in diverse societies. Thus, optimizing sleep duration and quality are important considerations in future clinical studies aimed at mitigating cognitive decline in older individuals.

REFERENCES

1. Bombois S, Derambure P, Pasquier F, Monaca C. Sleep disorders in aging and dementia. *J Nutr Health Aging* 2010;14:212-7.
2. Descamps A, Cespuglio R. Influence of aging on the sleep rebound induced by immobilization stress in the rat. *Brain Res* 2010;1335:14-23.
3. Crenshaw M, Edinger, J. Slow-wave sleep and waking cognitive performance among older adults with and without insomnia complaints. *Physiol Behav* 1999;66:485-92.
4. Faubel R, López-García E, Guallar-Castillón P, et al. Usual sleep duration and cognitive function in older adults in Spain. *J Sleep Res* 2009;18:427-35.
5. Nebes RD, Buysse DJ, Halligan EM, Houck PR, Monk TH. Self-reported sleep quality predicts poor cognitive performance in healthy older adults. *J Gerontol* 2009;64:180-7.
6. Matthews K, Gallo L. Psychological perspectives on pathways linking socioeconomic status and physical health. *Annu Rev Psychol* 2011;62:501-30.
7. Stamatakis KA, Kaplan GA, Roberts RE. Short sleep duration across income, education, and race/ethnic groups: population prevalence and growing disparities over 34 years of follow-up. *Ann Epidemiol* 2007;17:948-55.
8. Lallukka T, Ferrie JE, Kivimäki M, et al. Economic difficulties and subsequent sleep problems: Evidence from British and Finnish occupational cohorts. *Sleep Med* 2012;13:680-5.
9. Mezick EJ, Matthews KA, Hall M, et al. Influence of race and socioeconomic status on sleep: Pittsburgh SleepSCORE project. *Psychosom Med* 2008;70:410-16.
10. Baldwin CM, Kapur VK, Holberg CJ, Rosen C, Nieto FJ. Associations between gender and measures of daytime somnolence in the Sleep Heart Health Study. *Sleep* 2004;27:305-12.
11. Haimov I, Shatil E. Cognitive training improves sleep quality and cognitive function among older adults with insomnia. *PLoS One* 2013;8:e61390.
12. Keage HA, Banks S, Yang KL, Morgan K, Brayne C, Matthews FE. What sleep characteristics predict cognitive decline in the elderly? *Sleep Med* 2012;13:886-92.
13. Kowal P, Chatterji S, Naidoo N, et al. Data resource profile: The WHO Study on Global Ageing and Adult Health (SAGE). *Int J Epidemiol* 2012;41:1639-49.
14. United Nations Educational, Scientific and Cultural Organization. International Standard Classification of Education 1997; (ISCED 97), 2006. www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm
15. Patel SR, Malhotra ADJG, Gottlieb DJ, White DP, Hu FB. Correlates of long sleep duration. *Sleep* 2006;29:881-9.
16. Tamakoshi A, Ohno Y. Self-reported sleep duration as a predictor of all-cause mortality: results from the JACC study, Japan. *Sleep* 2004;27:51-4.
17. Ohayon MM, Vecchierini M. Normative sleep data, cognitive function and daily living activities in older adults in the community. *Sleep* 2005;28:981-9.
18. Grodstein F, Chen J, Willett WC. High-dose antioxidant supplements and cognitive function in community-dwelling elderly women. *Am J Clin Nutr* 2003;77:975-84.
19. Scarmeas N, Albert SM, Manly JJ, Stern Y. Education and rates of cognitive decline in incident Alzheimer's disease. *J Neurol Neurosurg Psychiatry* 2006;77:308-31
20. Goel N, Rao H, Durmer JS, Dinges DF. Neurocognitive consequences of sleep deprivation. *Semin Neurol* 2009;29:320-39.
21. Xu L, Jiang CQ, Lam TH, et al. Short or long sleep duration is associated with memory impairment in older Chinese: the Guangzhou Biobank Cohort Study. *Sleep* 2011;34:575-80.
22. Mander BA, Rao V, Lu B, et al. Prefrontal atrophy, disrupted NREM slow waves and impaired hippocampal-dependent memory in aging. *Nat Neurosci* 2013;16:1-10.
23. Wolkove N, Elkholy O, Baltzan M, Palayew M. Sleep and aging: Sleep disorders commonly found in older people. *CMAJ* 2007;176:1299-304.
24. Stenholm S, Kronholm E, Bandinelli S, Guralnik JM, Ferrucci L. Self-reported sleep duration and time in bed as predictors of physical function decline: results from the InCHIANTI Study. *Sleep* 2011;34:1583-93.
25. Lockley SW, Skene DJ, Arendt J. Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. *J Sleep Res* 2002;8:175-83.

ACKNOWLEDGMENTS

The authors thank Nirmala Naidoo for assistance with data analysis, Larry Sugiyama for discussions of the project, all the participants in the study, and the study PIs and teams.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication August, 2013
Submitted in final revised form January, 2014
Accepted for publication January, 2014

Address correspondence to: Theresa E. Gildner, Department of Anthropology, University of Oregon, Eugene, OR 97403; Tel: (541) 346-5102; Fax: (541) 346-0668; E-mail: tgildner@uoregon.edu

DISCLOSURE STATEMENT

This was not an industry supported study. Support for the research was provided by NIH NIA Interagency Agreement YA1323-08-CN-0020 with the World Health Organization and grant NIH R01-AG034479. The funding organizations had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors have indicated no financial conflicts of interest.