Sleep Duration and Cognition in a Nationally Representative Sample of U.S. Older Adults

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Abstract

Objectives: Excessive and insufficient sleep have been associated with cognitive dysfunction in older adults in U.S. and non-U.S. studies. However, the U.S. studies were not in nationally representative samples. We investigated the association between sleep duration and cognitive performance in a nationally representative sample of U.S. older adults.

Participants: We studied 1,496 survey participants aged 60 years from the National Health and Nutrition Examination Survey (NHANES) 2013-14 dataset.

Measurements: Our primary predictor was weekday (or workday) nighttime sleep duration, categorized as 2-4, 5, 6, 7 (reference), 8, 9, and 10 hours. We studied five cognitive outcomes: Consortium to Establish a Registry for Alzheimer's Disease Word Learning (CERAD-WL) Immediate Recall, CERAD-WL Delayed Recall, Animal Fluency Test (AFT), Digital Symbol Substitution Test (DSST), and subjective cognitive problems (SCP).

Results: After adjusting for age, sex, race, education, depressive symptoms, and sedative-hypnotic use, sleep duration of 10 hours was significantly associated with lower scores on CERAD-WL Immediate Recall, CERAD-WL Delayed Recall, AFT, and DSST, and greater odds

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of SCP; sleep duration of 8 hours was associated with lower CERAD-WL delayed recall scores: 8 hours, 9 hours, and 10 hours. After adjustment, there were no significant associations of shorter sleep duration with cognition.

Conclusions: In U.S. adults aged 60 years, long nighttime weekday or workday sleep duration is associated with poorer verbal memory, semantic fluency, working memory, and processing speed in addition to greater odds of self-reported cognitive problems. Long sleep duration may be a marker of fragmented sleep or neurodegeneration in U.S. older adults.

Objective

A growing body of literature has highlighted the critical role sleep plays in the cognitive and general health in older adults.[1,2] While there are numerous metrics of sleep quality and quantity, sleep duration is of particular interest given its conceptual accessibility to community-dwelling older adults and the relative ease with which it can be queried in large epidemiologic samples. The recommended sleep duration for adults aged 65 years and older, per National Sleep Foundation guidelines, is 7 to 8 hours per night.[3] Although some studies suggest that community-dwelling older adults' median sleep duration is about 7 hours,[4] many older adults habitually sleep for more or fewer hours than recommended.[5,6] This is important, because short and long sleep have been found to be associated with multiple health conditions, including diabetes, coronary heart disease-related events, and all-cause mortality.[7–10]

In the multinational, non-U.S., nationally representative Study on Global Aging and Adult Health (SAGE) of older adults (50 years old), Gildner et. al. observed both short and long sleep durations to be associated with poorer cognitive performance.[11] More specifically, the extremes of sleep duration were associated with poorer scores on tests of verbal fluency, digit span (forwards and backwards), and verbal recall (immediate and delayed), compared to those with intermediate sleep durations of 6-9 hours.[11]

U.S and non-U.S. studies that were not nationally representative have produced similar results. For example, in a prospective study of older adults in Guangzhou, China, Xu et. al. found both short and long sleep to be associated with lower scores on both global cognitive function and verbal memory.[12] In a cross-sectional telephone survey of older adults in Paris, France, Ohayon et. al. found that sleep duration of 6 hours or less was associated with worse cognitive impairment.[4] In the Northern Manhattan Study (NOMAS), Ramos et. al. noted an association between long sleep of 9 hours or more and poorer global cognition scores.[13]

Although the aforementioned studies evaluated various segments of the older adult population either in the U.S. or abroad, there remains a gap in knowledge about the association between sleep duration and performance across cognitive domains in a nationally representative sample of community-dwelling older adults in the U.S. Such knowledge could help inform U.S. guidelines about sleep duration for cognitive health. In this study, we evaluated the association of self-reported weekday or workday sleep duration with four measures of cognitive performance, covering a range of cognitive domains, and subjective cognitive problems in a nationally representative sample of community-dwelling U.S. older adults.

Methods

Participants

The National Health and Nutrition Examination Survey (NHANES) is a bi-yearly national survey of the U.S. children and adults. The survey consists of an in-home interview and an examination at a Mobile Examination Center (MEC). The 2013-14 NHANES sample had 10,175 children and adult participants. Of these, 1,841 were aged 60 years or older and had undergone the general interview. Among participants aged 60 and older, 56 only completed the in-home interview without completing the MEC exam and 1,785 participated in both the in-home interview and the examination at the Mobile Examination Center (MEC). Of these 1,785 participants, 19 were ineligible for the cognitive testing because they required a proxy for it; 16 were ineligible because they did not understand the supported languages of the cognitive testing; and 64 had no testing done. Of the 1,686 who remained, 1,638 completed all three cognitive tests. We excluded 5 of these 1,638 participants without complete data on sleep duration and an additional 137 without complete data on subjective cognitive problems or the covariates of interest. Thus, our final analytic sample consisted of 1,496 participants (Figure 1).

Of these, there were 8 participants who required a proxy for the in-home interview (including the sleep measures), but not for the cognitive evaluation; these participants were included in the analysis. Since one of the eligibility requirements for the cognitive evaluation was the ability to complete the cognitive evaluation without a proxy, none of the NHANES participants had a proxy for the cognitive evaluation. A sensitivity analysis was performed excluding the 8 participants who required a proxy for the in-home interview. We did not find the results to be significantly different, so we retained them in our sample.

Measures

Demographics, sleep duration, and questionnaire data were obtained during in-home interviews. The age at the time of the survey was recorded in years for participants aged 80 and younger. For participants over the age of 80, their age was recorded as 80 in the dataset released by NHANES, to reduce the risk that the oldest participants could be identified. Cognitive data were acquired during MEC visits.

Sleep duration.

Survey participants (SP) or their proxies were asked "How much sleep {do you/does SP} usually get at night on weekdays or workdays?" Responses were given in units of hours. We categorized responses as 4 hours, 5 hours, 6 hours, 7 hours (reference), 8 hours, 9 hours, and 10 hours. We chose 7 hours as the reference, because it has been identified as the median sleep duration in older adults and has been used as a reference in prior studies of sleep duration and cognition in older adults.[4,14]

Cognitive tests.

Participants completed four cognitive tests: the Consortium to Establish a Registry for Alzheimer's Disease Word Learning (CERAD-WL) (immediate and delayed recall),[15]

Animal Fluency Test (AFT),[16] and Digital Symbol Substitution Test (DSST).[17] Voice recordings were required for the CERAD-WL and Animal Fluency Tests (AFT). If consent was not obtained for voice recording, only the DSST was administered.

The CERAD-WL is a measure of verbal memory and consists of four trials. During the first three trials, participants were asked to read ten words aloud, and then to immediately recall them. The sum of correctly recalled words across the three trials served as the immediate recall score (possible range 0 to 30). Following completion of the AFT and DSST (approximately 8-10 minutes after starting the CERAD-WL), participants were asked to recall as many of the ten words as they could, and the total number of correctly recalled words served as their delayed recall score.

The AFT assesses semantic fluency. Participants were asked to name as many animals as they could within one minute. The total number of animals named served as their score.

The DSST, from the Wechsler Adult Intelligence Scale (WAIS III), is a test of sustained attention, processing speed, and working memory.[17] Participants were given an examination sheet with a row of numbers and symbols at the top that served as a key. Below the key is an array of 122 numbers, and participants were asked to draw the appropriate symbol next to each number as quickly as they could within two minutes.

Subjective cognitive problems.

NHANES also collected information on subjective cognitive problems. The Medical Conditions Questionnaire asked participants or proxies about "…difficulties in thinking or remembering…like confusion or memory loss that are happening more often or getting worse" over the past 12 months, with response options of yes or no. They were also asked in the Physical Functioning Questionnaire, whether they are "limited in any way because of difficulty remembering [due to] periods of confusion?" We classified participants with responses of yes to either question as having subjective cognitive problems. Participants missing one of these items were excluded from analyses.

Other measures.

NHANES participants provided information on demographic characteristics. Depressive symptoms were measured using the Patient Health Questionnaire.[18,19] Blood pressure and diabetes history were obtained during an in-home interview by asking "{Have you/Has SP} ever been told by a doctor or other health professional that {you/s/he} had hypertension, also called high blood pressure?" and "{Other than during pregnancy, {have you/has SP}/{Have you/Has SP}} ever been told by a doctor or health professional that {you have/{he/she/SP} has} diabetes or sugar diabetes?" Interviewers also collected information on prescription medications by first asking the participant whether they took prescription medications in the last 30 days. If they answered in the affirmative, the interviewer would ask the participant to show him or her the prescription bottles. If the bottles were not available, the interviewer relied on the participant's verbal report. Participants were classified as being on sedative medications if at least one of their medications was categorized by NHANES as an anxiolytic, sedative, or hypnotic.

Statistical Analyses

We computed descriptive statistics and compared participants across sleep duration categories using linear regression for continuous variables, logistic regression for binary variables, and Chi-squared tests for categorical variables. Covariates associated with self-reported sleep duration and at least 1 of the 4 measures of cognitive function or subjective cognitive problems at the p <0.10 level were included in the multiple regression models; sex and education (some college or higher) were also included for face validity. We performed unadjusted and adjusted multiple regression analyses with sleep duration as the predictor and cognitive test score or subjective cognitive problems as the outcome. We conducted tests for linear trend across sleep duration categories. All analyses were performed with Stata/IC 15.1 (Statacorp, College Station, TX) with sample weights applied to make results nationally representative. Because NHANES uses a complex multistage, probability sampling design, we also accounted for primary sampling units and strata, using Taylor series approximations.

Results

Participants had a mean age of 69.3 ± 0.3 years (mean ± standard error). The range of the participants' ages had a lower limit of 60 years. However, the upper limit is unknown because participants whose age was greater than 80 years had their age recorded as 80 years in the dataset released by NHANES to reduce the risk of identifying participants. Per NHANES documentation, the weighted mean age for those aged above 80 was 84 years. In this sample, there were 245 participants who were recorded as 80 years of age. Overall, 46.1% were male, 79.3% identified themselves as White, and 63.4% reported at least some college education (Table 1). With respect to sleep duration, 61 (4.1%) reported 2-4 hours of sleep, 110 (7.4%) reported 5 hours of sleep, 318 (21.3%) reported 6 hours of sleep, 406 (27.1%) reported 7 hours of sleep, 430 (28.7%) reported 8 hours of sleep, 104 (7%) reported 9 hours of sleep, 67 (4.5%) reported 10 or more hours of sleep. Sleep duration was significantly associated with age, race, hypertension, depressive symptoms, and sedative use. Means ± standard errors of participants' performance on the cognitive tests were also calculated by sleep-duration category (Table 2).

CERAD-WL Immediate Recall

Compared to participants reporting 7 hours of sleep, performance on CERAD-WL immediate recall was poorer among those reporting sleep durations of 5 hours (B = −1.36, 95% confidence interval (CI) −2.59, −0.13), 8 hours (B = −1.04, 95% CI −1.82, −0.27), and 10 or more (B = −2.57, 95% CI −3.79, −1.36) (Table 3). After adjusting for age, sex, race, education, depressive symptoms, and sedative medications, only sleep duration of 10 or more hours remained significantly associated with lower CERAD-WL immediate recall score (B = −2.11, 95% CI −3.43, −0.80). There was a linear trend, such that, among participants sleeping ⩾ 7 hours those with longer sleep had poorer CERAD-WL immediate recall scores, even after adjustment.

CERAD-WL Delayed Recall

In unadjusted models, CERAD-WL delayed recall scores were also poorer among those with longer sleep compared to those sleeping 7 hours, specifically those reporting 8 hours (B =

−0.66, 95% CI −1.10, −0.22), 9 hours (B = −1.01, 95% CI −1.84, −0.19), and 10 or more hours (B =−1.58, 95% CI −2.55, −0.62). In adjusted multiple regression analysis, compared to those reporting 7 hours sleep, scores were lower among participants reporting sleep durations of 8 hours (B = −0.45, 95% CI −0.84, −0.06), 9 hours (B = −0.69, 95% CI −1.33, −0.05) and 10 hours (B = −1.36, 95% CI −2.42, −0.30). Among participants reporting 7 hours of sleep, those reporting longer sleep had worse CERAD-WL delayed recall scores, even after adjustment (Table 3).

Animal Fluency Test

In the unadjusted model, compared to 7 hours of sleep, both shorter and longer sleep durations were associated with poorer AFT performance: 2-4 hours (B = −1.86, 95% CI −3.19, −0.52), 6 hours (B = −1.39, 95% CI −2.47, −0.30), and 10 or more hours (B = −3.78, 95% CI −6.16, −1.40) (Table 4). In the adjusted model, however, only sleep of 10 hours or more was associated with poorer AFT performance (B = −3.20 95% CI −5.77, −0.62). There was again a linear trend, such that, among participants sleeping 7 hours, those with longer sleep duration had poorer performance on the AFT, even after adjustment (Table 4).

Digit Symbol Substitution Test

In unadjusted analyses, compared to participants sleeping 7 hours, lower scores were observed among those reporting sleep durations of 5 hours (B = −5.59 95% CI −10.41, −0.77), 6 hours (B = −3.60 95% CI −7.07, −0.13), 8 hours (B = −3.82 95% CI −7.24, −0.39), and 10 or more hours (B = −10.05 95% CI −14.54, −5.56). After adjustment for covariates, only sleep durations of 10 hours or greater were associated with poorer DSST scores (B = −7.56 95% CI −11.52, −3.60). Among participants reporting 7 hours of sleep a night, those with longer sleep durations had poorer DSST scores, even after adjustment (Table 4).

Subjective Cognitive Problems

In unadjusted analyses, relative to those who slept 7 hours, self-reported cognitive problems were more prevalent among those who slept 2-4 hours (OR = 5.06, 95% CI 1.80, 14.26), 6 hours (OR = 1.83, 95% CI 1.02, 3.30), 8 hours (OR = 1.91, 95% CI 1.21,3.01), 9 hours (OR = 2.31, 95% CI 1.33, 4.00), and 10 or more hours (OR = 4.19, 95% CI 1.76, 9.93). After adjusting for age, sex, race, education, depressive symptoms, and sedative medications, compared to those sleeping 7 hours, sleep durations of 10 or more hours (OR = 3.61, 95% CI 1.42, 9.22) were associated with higher odds of subjective cognitive problems (Table 5). There was a linear trend among participants sleeping 7 hours, such that those with longer sleep had greater odds of reporting subjective cognitive problems, even after adjustment (Table 5).

Conclusions

We investigated the association of self-reported sleep duration with performance on objective cognitive tests and subjective cognitive problems in a nationally representative sample of community-dwelling U.S. adults aged 60 and older. After accounting for several potential confounders, we found that longer, but not shorter sleep duration, was associated with poorer cognitive performance and subjective cognitive problems. Notably, participants

reporting 10 hours or more sleep had lower scores in all four cognitive tests, which measured immediate and delayed verbal memory, semantic fluency, and sustained attention, processing speed, and working memory; they also had greater odds of subjective cognitive problems. Additionally, a linear trend was found across normal-to-longer sleep duration (7 hours), but not normal-to-shorter sleep duration (7 hours), such that longer sleep was associated with poorer performance on all four cognitive tests and greater odds of subjective cognitive problems, even after adjustment for covariates.

Our findings are consistent with those from several prior studies. For instance, similar to our results, Ramos et. al. found that among older adults in the NOMAS, those reporting 9 hours of sleep had lower MMSE scores after adjustment for demographics, medications, vascular risk factors, and sleep-disordered breathing risk factors.[13] Also, consistent with our results, they found no significant association between shorter sleep duration and cognitive performance.[13] Likewise, in a study of non-institutionalized older adults in Spain, Faubel et. al. found that self-reported long sleep (11 hours), but not short sleep (<7 hours) over a 24-hour period, was associated with lower performance on a Spanish version of the MMSE.[14] Although the magnitudes of the differences in cognitive performance we observed among the sleep duration groups compared to the reference group were small, they are comparable to those found in other studies of self-reported sleep duration and cognition, including those by Gildner et al., Xu et al., and Ramos et al.[11–13] Future longitudinal studies in nationally representative samples of U.S. older adults may elucidate whether these differences remain subtle or increase over time.

Where objectively measured sleep is concerned, actigraphy-based studies have found associations between long sleep duration and poorer cognitive performance, but not short sleep duration. In the Study of Osteoporotic Fractures (SOF), among older women who completed wrist actigraphy, those in the longest tertile of total sleep time had poorer scores on the Modified Mini-Mental Status Exam, and measures of both semantic and phonemic fluency than those in the middle tertile; the performance of those in the shortest and middle tertiles did not differ.[20]

The association between longer sleep and poorer cognitive scores suggests one of two possibilities: either long sleep is a marker of poor health[21] or long sleep is itself detrimental for cognitive performance. Given the lack of biological plausibility, the latter is unlikely. The more plausible explanation is that longer sleep is a marker of sleep fragmentation,[22] which in turn has been linked to poorer cognitive performance.[23] Fragmented sleep may be a marker of either underlying neuropathology or sleep apnea.[24] In a prospective study, long sleep duration was demonstrated to be a risk factor for incident dementia and may have been an early proxy marker for underlying neurodegenerative disease.[6] Also, obstructive sleep apnea, which can lead to sleep fragmentation,[22] has likewise been shown to be a risk factor for dementia.[2,25] The differential diagnosis of long sleep includes but is not limited to obstructive sleep apnea and potentially early, preclinical stages of neurodegenerative disorders, such as Alzheimer's disease.[2,6,22–25]

It is of interest that the results of this study differed from studies that found a statistically significant association between short sleep and poorer cognition. In a study of older adults in

the Chinese province of Guangzhou by Xu. et. al., both self-reported short and long sleep durations were found to be associated with lower scores on global cognitive function and delayed verbal recall.[12] Sleep durations 6 hours and 9 hours were associated with lower scores on MMSE; sleep durations of 5 hours and 10 hours were associated with lower scores on delayed verbal recall.[12] Additionally, in a 2014 nationally representative non-U.S. study of sleep duration and sleep quality among older adult participants of the SAGE study in India, China, Russian Federation, Ghana, Mexico, and South Africa, Gildner et. al. found that both those with self-reported short sleep duration and those with self-reported long sleep duration had poorer performance on tests of verbal fluency, backwards and forwards digit span, and immediate and delayed verbal recall.[11] The study of older adults in Paris by Ohayon et. al. had revealed that self-reported sleep durations of 4 hours or less were associated with cognitive impairment, as gauged by the Cognitive Difficulties scale.[4] There are several potential reasons we did not find a statistically significant association between short sleep and cognitive performance. One possibility is that our largely null results for shorter sleep duration may be due to insufficient statistical power. The Guangzhou study had 13,888 participants, and the SAGE study had 35,552, whereas our study sample was comprised of 1,496 respondents. Additionally, these studies may have had different findings because they employed different cognitive batteries. Also, we did not exclude the extremes of self-reported sleep duration as Xu et. al. had. We included more extreme sleep durations in our analysis to deliver a more comprehensive representation of the older population and to preserve statistical power. Lastly, age differences may account for some of the discrepant findings. For example, the studies by Xu et. al. and the Gildner et. al. included adults age 50 years, but we only studied adults aged 60 years.

This study also had some limitations. First, the NHANES uses a cross-sectional design which precludes a longitudinal analysis that might provide insight into the directionality and time course of the link between sleep and cognitive performance. In addition, our sample contained only non-institutionalized participants, and results may not generalize to institutionalized older adults. Further, our data were based on self-reported weekday or workday nighttime sleep duration, and the NHANES did not assess sleep duration on weekends or days off, daytime sleep duration, or include objective sleep measures in the 2013-2014 sample. Our data also did not include sleep diaries or polysomnography. Previous studies have found that objective and subjective measures frequently disagree, and that in older people this may be due to cognitive problems.[26] Therefore, the self-reported sleep durations collected in our sample may not have captured all participants' true sleep durations. Further, our sample included 8 participants who required proxies for the in-home interview, which includes the sleep questionnaire. Although the validity of proxy-reported sleep duration in older adults in unknown, it is likely to be vulnerable to the aforementioned inaccuracies of self-reported sleep without proxy in addition to the inaccuracies that may come with proxy reporting. However, it is also possible that a proxy observer may provide a more accurate history if a survey participant has memory problems. We completed a sensitivity analysis excluding those with proxies and did not find a significant change in the results, so we included them in our sample. In addition, the ages of participants older than 80 years were recorded as 80 in the datasets released by NHANES to reduce the risk of identifying participants in this age group. Per NHANES documentation, the average age of

participants aged over 80 was 84 years. In our study, 245 out of the 1,496 participants were recorded as having age 80 years. This measure against disclosure risk protects participants but likely results in an underestimation of the ages of participants and may have limited this study's ability to adjust for age, an important risk factor for cognitive decline. Also, our study population was relatively young. Although we cannot be certain of the exact ages of those recorded as aged 80 years, 1,251 out of 1,496 participants were aged 60 to 79 years. Thus, findings may not generalize to adults who are significantly older than our study population. Further, the NHANES 2013-14 sleep questionnaire did not collect data regarding obstructive sleep apnea, which is an important potential confounder of the relationship between sleep duration and cognition. Additionally, the measures of subjective cognitive problems were based on questions about memory and confusion from the medical condition and physical function questionnaire; the psychometric properties of these items are unknown and require further study. Finally, the classifications of participants as taking or not taking sedative medications was limited by the method of data collection, which relied on self-report if participants' medication bottles were not available. A more objective means of assessment would enhance the measurement of sedative use.

Our study also has important strengths. First, prior studies in this area include several U.S. studies that were not nationally representative and a nationally representative non-U.S. study. The present study, however, investigated sleep duration-cognition links in a nationally representative sample of non-institutionalized U.S. older adults. Although the National Sleep Foundation has published sleep duration recommendations by age that include older people, [3] the Sleep Research Society and the American Academy of Sleep Medicine have not yet issued guidelines for sleep duration for individuals over age 60.[27] Our findings could be used to inform these recommendations with regard to the outcome of cognitive health. Second, because NHANES collected data on performance on well-studied cognitive tests from different domains and a measure of subjective cognitive problems, this yielded a more nuanced picture of how various cognitive domains vary in their association with sleep duration than have studies using global cognitive tests such as the MMSE. Although subjective cognitive impairment (SCI) is still controversial, it may be a useful marker of underlying brain pathology and thus warrants investigation.[28]

In conclusion, compared to community-dwelling U.S. older adults reporting seven hours of nighttime sleep on weekdays or workdays, those reporting longer sleep duration have poorer objective and subjective cognitive performance. Future studies of both daytime and nighttime sleep in relation to cognitive performance and decline in representative samples are needed, particularly those involving objective measures (e.g., wrist actigraphy). Such studies would add to our understanding of the link between sleep duration and cognitive outcomes. This knowledge could be used to inform public health policy, clinical guideline development, and both clinical assessment and practice.

Acknowledgments

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What is the primary question addressed by this study?—

The question addressed by the study must limited to only one sentence.

Although studies have found links between the extremes of sleep duration and cognitive performance, there is a lack of these studies in nationally representative samples of U.S. older adults.
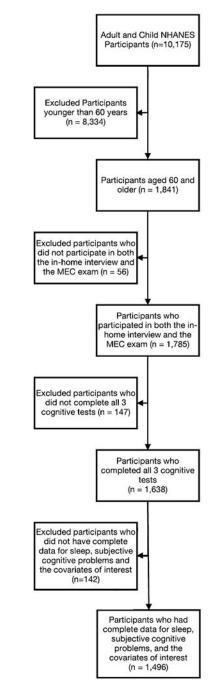
What is the main finding of this study?—

The finding must be limited to two sentences.

We found that longer self-reported sleep duration was linked to poorer cognitive performance and greater odds of subjective cognitive problems in a nationally representative sample of U.S. older adults.

What is the meaning of the finding?—

The meaning of the finding must be limited to one sentence.

Long sleep duration may be a marker of disturbed (e.g., fragmented) sleep, which may be due to sleep apnea or neurodegeneration, in U.S. older adults.

Figure 1.
Participant Flow Diagram

Table 1.

Participant Characteristics (mean ± standard error or n (%)) by Sleep Duration

	Sleep Duration (Hours)							F stat	df	p-value[†]
	2 - 4	5	6	7	8	9	10			
n	61 (4.1)	110 (7.4)	318 (21.3)	406 (27.1)	430 (28.7)	104 (7.0)	67 (4.5)			---
Age	66.5± 0.9	69.5 ± 1.0	68.9 ± 0.5	68.4 ± 0.4	70.0 ± 0.3	71.0 ± 0.8	70.2 ± 1.4	5.08	6, 10	0.0122
Male	21 (34.1)	50 (37.3)	147 (42.9)	210 (52.6)	208 (44.7)	54 (50.2)	27 (34.2)	1.88	6, 10	0.1799
White	16 (55.7)	35 (62.8)	131 (69.9)	229 (84.9)	241 (82.2)	68 (86.2)	42 (84.1)	7.97	6, 10	0.0024
College	20 (47.8)	47 (55.4)	165 (61.1)	235 (69.0)	233 (61.4)	64 (69.8)	26 (56.7)	1.88	6, 10	0.1796
Obese	27 (47.4)	47 (51.7)	118 (41.4)	148 (36.8)	146 (33.5)	42 (41.8)	25 (37.5)	2.07	6, 10	0.1477
DM	12 (13.3)	29 (22.8)	79 (25.7)	86 (17.3)	93 (17.6)	29 (20.0)	16 (22.3)	1.28	6, 10	0.3492
HTN	37 (41.4)	77 (72.9)	210 (65.1)	234 (53.1)	281 (63.9)	71 (65.2)	44 (70.8)	2.34	6, 10	0.1131
Dep. Sx.	8.1 ± 1.1	4.6 ± 0.5	4.0 ± 0.2	2.2 ± 0.2	2.9 ± 0.3	3.8 ± 0.6	3.0 ± 0.5	6.02	6, 10	0.0067
Sedative Use	5 (6.4)	12 (17.3)	25 (8.1)	25 (6.3)	40 (11.6)	16 (22.2)	8 (12.3)	6.37	6, 10	0.0055

Key: College = have at least some college education, Dep. Sx. = Depressive Symptoms, DM = Diabetes Mellitus, HTN = Hypertension

[†]Survey-weighted linear and logistic regression; P-value is of the F-statistic, df = degrees of freedom, F stat = F statistic

Table 2.

Participant Performance on Cognitive Tests (mean ± standard error or n (%)) by Sleep Duration

	Sleep Duration (Hours)							F stat	df	p-value[†]
	2 - 4	5	6	7	8	9	10			
n	61 (4.1)	110 (7.4)	318 (21.3)	406 (27.1)	430 (28.7)	104 (7.0)	67 (4.5)			---
CERAD Im.	20.2 ± 0.7	19.9 ± 0.7	20.4 ± 0.3	21.3 ± 0.4	20.2 ± 0.2	19.8 ± 0.6	18.7 ± 0.8	4.96	6, 10	0.0132
CERAD Del.	6.5 ± 0.3	6.6 ± 0.4	6.7 ± 0.1	7.0 ± 0.2	6.4 ± 0.1	6.0 ± 0.3	5.5 ± 0.5	3.93	6, 10	0.0279
AFT	17.1 ± 0.6	17.8 ± 1.0	17.5 ± 0.4	18.9 ± 0.5	18.1 ± 0.2	17.7 ± 0.4	15.1 ± 0.8	6.66	6, 10	0.0047
DSST	49.1 ± 2.9	49.1 ± 2.4	51.1 ± 1.1	54.7 ± 1.3	50.9 ± 1.1	52.4 ± 3.0	44.6 ± 2.0	5.63	6, 10	0.0086

Key: CER. Im. = CERAD-WL Immediate recall, CER. Del. = CERAD-WL Delayed Recall, AFT = Animal Fluency Test, DSST = Digit Symbol Substitution Test

[†]Survey-weighted linear regression; P-value is of the F-statistic, df = degrees of freedom, F stat = F statistic

Table 3.

CERAD-WL Immediate and Delayed Recall Performance by Sleep Duration (B, 95% CI)

	Linear trend[†] (≤7h)			Sleep Duration, Hours per Day							Linear trend[†] (≥7h)		
	F stat	df	p-value	2-4	5	6	7	8	9	10	F stat	df	p-value
				B (95% CI)	B (95% CI)	B (95% CI)		B (95% CI)	B (95% CI)	B (95% CI)			
CERAD Word Learning Immediate Recall													
Unadjusted	2.08	1, 15	0.1696	−1.03 (−2.60, 0.54)	−1.36 (−2.59, −0.13)*	−0.84 (−1.71, 0.03)	Ref.	−1.04 (−1.82, −0.27)*	−1.51 (−3.21, 0.19)	−2.57 (−3.79, −1.36)*	22.90	1, 15	**0.0002**
Adjusted[‡]	0.32	1, 15	0.5784	−0.50 (−1.78, 0.78)	−0.68 (−1.70, 0.35)	−0.43 (−1.25, 0.39)	Ref.	−0.65 (−1.33, 0.03)	−0.88 (−2.28, 0.53)	−2.26 (−3.85, −0.68)*	8.84	1, 15	**0.0095**
CERAD Word Learning Delayed Recall													
Unadjusted	4.48	1, 15	0.0514	−0.58 (−1.22, 0.06)	−0.41 (−1.05, 0.22)	−0.29 (−0.71, 0.13)	Ref.	−0.66 (−1.10, −0.22)*	−1.01 (−1.84, −0.19)*	−1.58 (−2.55, −0.62)*	14.66	1, 15	**0.0016**
Adjusted[‡]	0.13	1, 15	0.7285	−0.34 (−1.06, 0.38)	−0.09 (−0.51, 0.34)	−0.10 (−0.55, 0.35)	Ref.	−0.46 (−0.87, −0.05)*	−0.69 (−1.34, −0.04)*	−1.41 (−2.56, −0.27)*	7.04	1, 15	**0.0181**

*
$P < 0.05$

[‡]Adjusted for age, sex, race, education, depressive symptoms, and sedative medication use

[†]Contrast of marginal linear predictions, df = degrees of freedom, F stat = F statistic

Table 4.

Animal Fluency Test and Digit Symbol Substitution Test Performance by Sleep Duration (B, 95% CI)

	Linear trend[†] (≥ 7 h)			Sleep Duration, Hours per Day							Linear trend[†] (≤ 7 h)		
	F stat	df	p-value	2-4	5	6	7	8	9	10	F stat	df	p-value
				B (95% CI)	B (95% CI)	B (95% CI)		B (95% CI)	B (95% CI)	B (95% CI)			
Animal Fluency Test													
Unadjusted	3.83	1, 15	0.0691	−1.86 (−3.19, −0.52)*	−1.09 (−3.50, 1.32)	−1.39 (−2.47, −0.30)*	Ref.	−0.84 (−2.05, 0.37)	−1.18 (−2.38, 0.02)	−3.78 (−6.16, −1.40)*	14.38	1, 15	**0.0018**
Adjusted[‡]	0.10	1, 15	0.7613	−0.22 (−1.61, 1.16)	0.45 (−1.41, 2.31)	−0.42 (−1.45, 0.60)	Ref.	−0.10 (−1.30, 1.10)	−0.46 (−1.66, 0.74)	−2.90 (−5.68, −0.12)*	5.54	1, 15	**0.0327**
Digit Symbol Substitution Test													
Unadjusted	3.73	1, 15	0.0726	−5.58 (−11.67, 0.52)	−5.59 (−10.41, −0.77)*	−3.60 (−7.07, −0.13)*	Ref.	−3.82 (−7.24, −0.39)*	−2.33 (−9.58, 4.93)	−10.05 (−14.54, −5.56)*	15.47	1, 15	**0.0013**
Adjusted[‡]	< 0.01	1, 15	0.9977	0.06 (−4.88, 4.99)	−0.10 (−3.90, 3.70)	−0.25 (−3.26, 2.76)	Ref.	−1.17 (−3.87, 1.52)	1.12 (−4.08, 6.32)	−7.47 (−12.04, −2.91)*	8.84	1, 15	**0.0095**

*
P < 0.05

‡
Adjusted for age, sex, race, education, depressive symptoms, and sedative medication use

†
Contrast of marginal linear predictions, df = degrees of freedom, F stat = F statistic, CI = Confidence interval

Table 5.

Association of Sleep Duration with Subjective Cognitive Problems (OR, 95% CI)

	Linear trend† (≤ 7 h)			Sleep Duration, Hours per Day							Linear trend† (≥ 7 h)		
	F stat	df	p-value	2-4	5	6	7	8	9	>=10	F stat	df	p-value
				OR (95% CI)	OR (95% CI)	OR (95% CI)		OR (95% CI)	OR (95% CI)	OR (95% CI)			
Unadjusted	9.64	1, 15	**0.0073**	5.06 (1.80, 14.26)*	1.66 (0.66, 4.15)	1.83 (1.02, 3.30)*	Ref.	1.91 (1.21, 3.01)*	2.31 (1.33, 4.00)*	4.19 (1.76, 9.93)*	12.83	1, 15	**0.0027**
Adjusted‡	1.39	1, 15	0.2563	1.95 (0.62, 6.12)	0.81 (0.32, 2.08)	1.21 (0.60, 2.45)	Ref.	1.51 (0.99, 2.30)	1.33 (0.68, 2.60)	3.61 (1.42, 9.22)*	8.73	1, 15	**0.0098**

*
P < 0.05

OR = odds ratio, CI = confidence interval

‡
Adjusted for age, sex, race, education, depressive symptoms, and sedative medication use

†
Contrast of marginal linear predictions, df = degrees of freedom, F stat = F statistic