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Original Article

Age-associated differences in sleep duration in the US population: potential effects of disease burden

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A B S T R A C T

Objectives: We contrasted the relative risks (RR) of short [<7 h] and long [>8 h] sleep experienced by middle-aged (45–64 years) and older (≥65 years) adults, compared with young adults (20–44 years).
Methods: We utilized NHANES data (2005–2016), capturing sociodemographic, socioeconomic, and health-related data among US adults.
Results: The Relative Risk (RR) of short sleep between young and middle-aged adults did not differ [RR = 1.02, NS]. However, the RR of short sleep was significantly reduced among older participants [RR = 0.81, $p < 0.01$]. Middle-aged adults had significantly lower RR of long sleep [RR = 0.80, $p < 0.01$], whereas older adults had significantly greater RR of long sleep [RR = 1.41, $p < 0.01$]. Compared with young adults, older adults with or without increased disease burden had significantly lower RR of short sleep [RR = 0.81, $p < 0.01$ and RR = 0.80, $p < 0.01$], respectively. However, for middle-aged adults, the RR of short sleep did not differ whether they reported a greater disease burden. Relative to young adults, older adults with or without disease burden had higher RRs of long sleep [RR = 1.39, $p < 0.01$] and [RR = 1.45, $p < 0.01$], respectively. For middle-aged adults without disease burden, the RR of long sleep was lower than among young adults [RR = 0.72, $p < 0.01$].
Conclusions: Compared with young adults, older adults were not at increased risk for short sleep. Rather, they reported longer sleep time regardless of the presence of disease burden. Future studies should investigate longitudinal effects of aging on objective sleep time, with or without common diseases.

1. Introduction

Much of the evidence from the extant sleep literature suggests that older adults (≥65 years) might be less likely to obtain the recommended sleep amount (7–8 h habitually) [1,2]. This is in part fueled by data evidencing age-associated increases in difficulty initiating and/or maintaining sleep or reports of non-restorative sleep among older adults, triggering help-seeking behavior to resolve their sleep difficulty [3,4]. Published reports also point to a greater prevalence of short and long sleep durations among older adults, compared with their young counterparts [1–9]. These data are consistent with research tracking age-related decreases in the trajectories of habitual sleep duration [5]. They are also in line with results of an important meta-analysis, showing greater rates of short and long sleep whether sleep data were derived subjectively or objectively (e.g., actigraphy and polysomnography) [2].

Whereas the foregoing is consistent with the usual expectation that older adults habitually sleep less, there are other studies pointing to a possible age-associated increase in sleep duration or no meaningful decrement in sleep amount [17–19]. Indeed, data from a population-based cohort of Finish twins born between 1945 and 1957 showed that 71.1% of them slept well when assessed 36 years later, and that overall the presence of ill health could explain why some might sleep poorly [17]. This is consistent

Abbreviations: National Health and Nutrition Examination Survey Study, (NHANES); relative risks, (RR); confidence interval, (CI); New York University, (NYU).

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with findings from an analysis of data from the Environmental Protection Agency Time Use Study and the American Time Use Survey, showing that odds of short sleep were lower among older adults (≥65 years) [18]. Other research using community sampling (adults, ages 18–89 years) revealed no significant relations between increasing age and indices of self-reported sleep, whether or not psychological and medical health measures were adjusted [19]. These findings could be viewed as consistent with an inherent ability to sleep the required amount, which is likely potentiated by the greater opportunity older adults have to stay in bed longer.

Plausibly, chronic health conditions underlie the associations between increased age and extreme sleep durations among susceptible adults [9–11]. Published reports show increased disease burden among older adults was associated with both short [7,8] and long sleep [8]. More specifically, evidence points to a U-shaped relationship, such that short (<7 h) and long (>8 h) sleep durations were both associated with increased morbidity commonly observed among older adults [9–13,15]. Of importance are also findings that suggest the associations between sleep and disease burden could differ across ages [14–17,19,26,27,34]. This is perhaps best exemplified in research aimed at delineating associations between sleep duration and obesity. Two independent studies revealed age-dependent associations between sleep duration and body weight. Accordingly, shorter sleep durations among young adults were associated with increased body mass, while associations among older adults were showed a characteristic U-shaped relationship (i.e., short and long sleep durations were both associated with increased body mass) [14,15].

Using data from the National Health and Nutrition Examination Survey (NHANES– 2005–2016), we tested the hypothesis that there is no significant age-associated decrease in sleep duration among older Americans [17–20]. Specifically, we contrasted the relative risks of short [<7 h] and long [>8 h] sleep experienced by middle-aged adults (45–64 years) and older adults (≥65 years), compared with young adults (ages 20–44 years; referent); in planned analyses, healthy sleep was defined as sleep durations lasting between 7 and 8 h per the NIH guidelines [20,22,41]. Furthermore, consistent with data suggesting age-related associations of disease burden with sleep duration, we examined whether the presence of disease burden (defined as obesity, diabetes, and hypertension) contributes to the relative risks of short and long sleep duration [12,14–18,28,35–38].

2. Methods

2.1. Participants

In this study, we utilized data provided by participants in the National Health and Nutrition Examination Survey (NHANES) 2005–2016 [23]. NHANES is a survey conducted to assess and track over time the health and nutritional status of children and adults in the United States using a combination of interviews, physical examinations and laboratory tests, as well as surveys that capture demographic, socioeconomic, dietary, and health-related data. Findings from the NHANES have been used to determine the prevalence of and risk factors for major diseases [23].

The primary outcome variable in this study was habitual sleep duration, based on responses to the following survey question: On average, how many hours of sleep do you usually get at night? Respondents reported hours of sleep in whole numbers from 1 to 24, which ranged from 2 to 11 h in our current sample. Consistent with the National Institutes of Health's recommendation of 7–8 h of sleep per day for healthy adults [23], in the present analyses, we defined insufficient sleep as sleep duration less than 7 h and long sleep as sleep duration greater than 8 h. Analyses included all participants within the age range of 20–85 years old. Participants with missing values for age, sex, education, total household income, body mass index, hypertension, diabetes, sleep disorder diagnosis, and sleep duration variables were excluded from our planned analyses. The sampling weight of each participant was provided by the National Center for Health Statistics (NHANES data modules) [23].

2.2. Statistical analysis

The continuous variables were expressed as means and standard deviations (SD) and categorical variables were expressed as percentages (%). Differences in characteristics of participants between three aging groupings (20–44 years, 45–64 years, or ≥65 years) were compared using ANOVA for continuous variables and the weighted chi-squared test for categorical variables, respectively. Specifically, we compared sociodemographic characteristics (sex, education, total household income), medical conditions (self-reported diabetes, hypertension, and obesity [defined as Body Mass Index ≥30 kg/m^2]), and sleep-related measures. Self-reported diabetes was based on the question: Have you ever been told by a doctor or other health professionals that you have diabetes? Self-reported hypertension condition was based on this question: Have you ever been told by a doctor or other health professional that you have hypertension?" Sleep measures included reported habitual sleep duration and a sleep disorder diagnosis based on the following question: Have you ever been told by a doctor or other health professionals that you have a sleep disorder? We focus on obesity, diabetes, and hypertension because previous studies have shown that sleep duration is associated with these three conditions [14,16,28,35,36]. Participants with disease burden had at least one of the medical conditions (diabetes, hypertension, or obesity). We also explored whether results differed when we categorized levels of disease burden as follows: mild = 1 condition, moderate = 2 conditions, and severe = 3 conditions), referenced to no medical condition for each participant.

We estimated the relative risks of short [<7 h] and long [>8 h] sleep based on the application of a modified Poisson regression modeling [19], since logistic regression modeling may be suboptimal for a rigorous assessment of the prevalence of short sleep in the US population [1,6]. Poisson regression is a generalized linear model, which is suitable for data that represent counts of certain events in stochastically independent units, where the number of events is assumed to follow a Poisson distribution [25]. Thus, the modified Poisson regression, incorporating the robust error variance procedure, was used to optimize accuracy of the estimated relative risk (RR) [8]. The R-package "sandwich" was implemented to obtain the robust standard errors. We compared the estimated RR of short and long sleep for the age groupings of 45–64 years and ≥65 years, referenced to age grouping of 20–44 years, adjusting for effects of sex, education, income, obesity, hypertension, and diabetes [24]. We also derived the 95% confidence interval (CI) for each estimated RR along with their p-values. The adjusted RRs of short and long sleep for participants were computed in the first modeling series. Then, we assessed the association of disease burden with short sleep and long sleep, adjusting for sex, education, and income. Additional analyses to evaluate the interaction of each medical condition with age groupings and association between severity of medical conditions with short sleep and long sleep were performed. The NHANES sampling weights were applied to all analytic procedures, and p-values smaller than 0.05 were considered statistically significant. All statistical analyses were performed using the [R] software version 3.6.1 (http://www.r-project.org) [24].

3. Results

3.1. Demographics and health risks of the participants

The distribution of the demographic and health factors for participants in the three age groupings: 20–44 years, 45–64 years, and ≥65 years is shown in Table 1. We observed significant racial/ethnic differences in the distributions of participants across the three age groupings, but no significant sex-based differences were noted. Participants in the older age groupings were significantly less likely to have a high school degree or higher and reported lower income levels. Furthermore, participants in the older age groupings were significantly more likely to report sleep disorders and received a diagnosis of hypertension and diabetes. Participants of middle ages had greater rates of obesity compared to other age groups. The average sleep duration in the three age groupings were: (20–44 years: [6.98 ± 1.44 h], 45–64 years: [6.85 ± 1.48 h], and ≥65 years: [7.27 ± 1.58 h] [43,44], p < 0.001), suggestive of a J-shape relationship between sleep duration and age.

3.2. Relative risk of short and long sleep duration

As shown in Table 2, results of the multivariate-adjusted Poisson regression modeling indicated that the relative risk of reporting short sleep between young (20–44 years) and middle-aged (45–64 years) adults did not differ [RR = 1.02, NS]. However, the relative risk of short sleep was significantly reduced among participants ≥65 years [RR = 0.81, p < 0.01]. As indicated in Table 4, we also noted that middle-age adults (45–64 years) had significantly lower relative risk of reporting long sleep [RR = 0.80, p < 0.01], whereas adults ≥65 years had significantly greater risk of reporting long sleep [RR = 1.41, p < 0.01].

3.3. Short and long sleep duration: associations with disease burden

Compared with adults younger than 45 years old, older adults (≥65 years) with or without increased disease burden had significantly lower relative risks of reporting short sleep [RR = 0.81, p < 0.01 and RR = 0.80, p < 0.01], respectively (Table 3). However, for middle-aged adults (45–64 years), we noted no significant findings regarding the RR of reporting short sleep regardless of the presence of disease burden.

Relative to adults younger than 45 years old, older adults (≥65 years) with or without disease burden had higher RRs of reporting long sleep [RR = 1.39, p < 0.01] and [RR = 1.45, p < 0.01], respectively (Table 5). For middle-aged adults (45–64 years) without the presence of disease burden, the relative risks of reporting long sleep was lower than among adults younger than 45 years old [RR = 0.72, p < 0.01]. For middle-aged adults (45–64 years) with disease burden, the RR of reporting long sleep was 0.87, but results were not significant (p = 0.065).

The results of our analyses evaluating the interactions between each medical condition and age groupings are provided as Supplementary Tables 1 and 2 for risk of short and long sleep, respectively. Likewise, we provide results of our multivariate models of associations between severity of medical conditions with short sleep and long sleep Supplementary Tables 3–6 summarize the. The results were consistent with our main findings.

Table 2
Relative risk of reporting short sleep (<7 h vs. 7–8 h).

	RR	95% CI	95% CI	P
Age (45–64 years)	1.020	0.968	1.076	0.454
Age (≥ 65 years)	0.809	0.753	0.869	0.001
Race: non-Hispanic Black	1.488	1.421	1.558	0.001
Race: other	1.108	1.053	1.165	0.001
Female Sex	0.918	0.877	0.961	0.001
Education ≥ high school	0.960	0.910	1.014	0.143
Income ≥ $45,000	0.874	0.834	0.915	0.001
Diabetes	1.163	1.085	1.246	0.001
Obesity	1.123	1.071	1.177	0.001
Hypertension	1.014	0.960	1.070	0.621

Analysis was based on Poisson regression modeling. Ages 18–44 and Non-Hispanic White served as referents; covariates were race, sex, education, income, obesity, diabetes, and hypertension.

Table 3
Relative risk of reporting short sleep (<7 h vs. 7–8 h): Model testing hypothesized interactions of age groupings and disease burden.

	RR	95% CI	95% CI	p
Age (45–64) without disease burden	1.027	0.946	1.115	0.523
Age (45–64) with disease burden	1.017	0.953	1.086	0.608
Age (≥ 65) without disease burden	0.809	0.710	0.923	0.002
Age (≥ 65) with disease burden	0.802	0.742	0.867	0.001
Disease burden	1.147	1.077	1.221	0.001
Race: non-Hispanic Black Race	1.493	1.426	1.563	0.001
Race: other	1.110	1.055	1.168	0.001
Female Sex	0.921	0.880	0.963	0.001
Education ≥ high school	0.959	0.909	1.013	0.133
Income ≥ $45,000	0.872	0.833	0.914	0.001

Analyses was based on Poisson regression modeling, considering the potential interaction of age groupings with or without disease burden (defined as the presence of obesity, diabetes, or hypertension); covariates were race/ethnicity, sex, education, income. Ages 18-44 and Non-Hispanic White served as referents.

Table 1
Demographics and health risks of the participants in the NHANES study.

	20–44 years	45–64 years	≥65 years	p*
N	10,180	7884	5367	
Race Non-Hispanic White	39.1%	40.1%	56.5%	0.001
Non-Hispanic Black	20.6%	23.2%	17.8%	
Others	40.3%	36.6%	25.6%	
Female Sex	52.1%	51.1%	50.4%	0.104
Education Less than high school	19.6%	25.6%	32.4%	0.001
High school or higher	80.4%	74.4%	67.6%	
Total household income < $45,000	50.6%	48.5%	65.1%	0.001
≥ $45,000	49.4%	51.5%	34.9%	
Obesity	35.6%	41.8%	35.4%	0.001
Hypertension	12.6%	35.9%	57.0%	0.001
Diabetes	3.4%	17.0%	24.9%	0.001
Disease burden	41.9%	64.5%	77.6%	0.001
Sleep disorder	20.3%	31.8%	31.0%	0.001

*p-values were calculated based on chi-squared tests.

Table 4
Relative risk of reporting long sleep (>8 h vs. 7–8 h).

	RR	95% CI	95% CI	p
Age (45–64)	0.797	0.708	0.897	0.001
Age (≥ 65)	1.411	1.252	1.591	0.001
Race: non-Hispanic Black	1.115	1.005	1.238	0.040
Race: other	1.052	0.957	1.157	0.293
Female Sex	1.314	1.201	1.438	0.001
Education ≥ High school	0.895	0.811	0.988	0.028
Income ≥ $45,000	0.838	0.765	0.917	0.001
Diabetes	1.217	1.068	1.388	0.003
Obesity	1.092	0.995	1.198	0.063
Hypertension	1.015	0.915	1.126	0.777

Analyses was based on Poisson regression modeling. Ages 18–44 and Non-Hispanic White served as referents; covariates were race, sex, education, income, obesity, diabetes, and hypertension.

Table 5
Relative risk of reporting long sleep (>8 h vs. 7–8 h): Model testing hypothesized interactions of age groupings and disease burden.

	RR	95% CI	95% CI	p
Age (45–64) without disease burden	0.718	0.595	0.867	0.001
Age (45–64) with disease burden	0.868	0.747	1.009	0.065
Age (≥ 65) without disease burden	1.393	1.151	1.686	0.001
Age (≥ 65) with disease burden	1.449	1.269	1.654	0.001
Disease burden	1.086	0.953	1.238	0.214
Race: non-Hispanic Black	1.119	1.009	1.241	0.034
Race: other	1.056	0.961	1.161	0.256
Female Sex	1.314	1.201	1.437	0.001
Education ≥ High school	0.890	0.806	0.983	0.021
Income ≥ $45,000	0.839	0.766	0.918	0.001

Analyses was based on Poisson regression modeling, considering the potential interaction of age groupings with or without disease burden (defined as the presence of obesity, diabetes, or hypertension); covariates were race/ethnicity, sex, education, income. Ages 18–44 and Non-Hispanic White served as referents.

4. Discussion

Although there is ample evidence supporting age-associated changes in sleep patterns, the main finding of our analysis is that there is no age-associated decrease in sleep time. These findings run counter to previous findings, which have suggested that older adults, on average, do not habitually obtain the recommended amount of sleep (7–8 h). The average sleep duration in the three age groupings (20–44 years; 45–64 years; and ≥65 years) was 6.98 ± 1.44 h, 6.85 ± 1.48 h, and 7.27 ± 1.58 h], respectively. Indeed, adults ages 65 years or older slept on average 0.42 h longer than did those ages 45–64 years. Regardless of individual differences in reported demographic or medical conditions, our multivariate-adjusted analyses revealed that the relative risk of short sleep did not differ between young (20–44 years) and middle-aged (45–64 years) adults. However, the relative risk of short sleep among adults ages ≥65 years was significantly reduced. Consistent with these findings, we also noted that, relative to young adults, those in the middle-aged grouping had significantly lower relative risk of reporting long sleep, whereas adults ages ≥65 years had significantly greater risk of reporting long sleep.

The finding of no decrease in sleep duration among older adults is in stark contrast with previous studies demonstrating decreases in sleep duration, which is often touted as a direct effect of increased age [1,5,6,25]. Our general observation was that adults in the older age grouping (≥65 years) seemed to have been experiencing longer sleep time, whether sleep time was considered on a continuous gradient or categorized based on NIH guidelines [25]. Our results that older adults generally slept longer (20–44 years: 6.98 h vs ≥ 65 years: 7.27 h) are consistent with a recent study from the Older Finnish Twin Cohort, showing that sleep duration in 2011 averaged 7.34 h among adults ages 35–54 years old and 7.52 h among those ages 55 years or older [17].

We note that the estimated risks of short sleep (<7 h) and long sleep (>8 h) in our sample were strikingly similar to those observed in a representative population-based study enrolling US participants [28% and 8.5%, respectively] [19,33]. The convergence of our findings with above-referenced studies may be due in part to the similarities in the operational measurement of subjective sleep duration, although we used a more robust analytic approach. These findings are important given the evidence that older adults commonly experience daytime napping [9,30]. It is not known whether respondents in the NHANES study considered napping when prompted to report nighttime sleep duration, which might offer a plausible explanation for the observed increased in reported sleep time. It may also be that adults of retirement ages are in fact sleeping longer than are younger adults, who are often burdened by daily social obligations (e.g., jobs, caretaking, and parenting activities). Previous research demonstrates that individuals who transitioned from full-time work status to full-time retirement had longer sleep duration overall, possibly attributable to less stringent daily schedules [28].

Some have argued that the increased age-related disease burden necessarily compromises individuals' ability to sleep the recommended amount [2,5–8,20,21]. This is based partly on the evidence that long and short sleep durations are associated with increased pro-inflammatory processes [32,33], which increase the likelihood of developing chronic diseases. Reduced sleep duration has also been attributed to alterations in brain structures [10], and molecular processes [30], which are associated with biological aging [34]. Notwithstanding these findings, in the present study we found that among older adults (≥65 years) with increased disease burden, the relative risks of reporting short sleep remained significantly lower than their younger counterparts. Likewise, the risk of reporting long sleep among older adults remained significantly greater than their counterparts. For middle-aged adults (45–64 years), we noted no significant findings regarding the risks of reporting short sleep regardless of the presence of disease burden. Their risk of reporting long sleep remained low, but the effect bordered significance in the presence of disease burden ($p = 0.065$). Our findings do not support an ipso facto age-related decrease in sleep duration resulting from increased disease burden defined as the presence of obesity [14,17,18], diabetes [28,35] or hypertension [12,15,16]. While it is evident that several age-related diseases could affect sleep patterns, the amount of sleep older adults experience may not necessarily decrease; indeed, some older adults seem to be able to sleep longer. Conceivably, this finding may reflect a greater habituation to life changes, resilience, or quite simply a greater opportunity to stay in bed longer. Unfortunately, the role of bedtime on habitual sleep time could not be determined, as the amount of time spent in bed daily was not captured in the NHANES study.

It is also noteworthy that while we were able to demonstrate no age-related decline in sleep duration, we could not examine changes in physiological sleep architecture. This is important given decade of research showing that specific aspects of sleep architecture may be associated with particular disease entities. Such is the case when considering lifetime changes in slow wave sleep. Generally, older adults experience less slow wave sleep, compared with younger individuals. This component of sleep physiology has gained increased importance given the emerging evidence that reduced slow wave sleep is associated with increased accumulation of toxic protein aggregates (i.e., amyloid-β plaques and hyperphosphorylated tau tangles) in the brain; these are two novel biomarkers of brain injury that are involved in the pathogenesis of Alzheimer's disease [39–41]. Furthermore, it has been shown that the presence of slow wave sleep facilitates the glimphatic clearance of these brain metabolites, thus preventing amyloid-β and tau deposition in the brain [42]. Unfortunately, such physiologic data were not available for analysis, as NHANES does not capture data on sleep physiology, which is routinely assessed using polysomnography.

4.1. Limitations and strengths

There are a few limitations of the present study such as the use of a cross-sectional design, which preclude the ability to determine causality or to assess longitudinal effects of increased age on sleep duration. Additionally, self-reporting data may introduce the possibility of recall bias, which could affect the reliability of the sleep estimates. Another important limitation is that self-reported sleep time is often influenced by perceived time spent in bed, and it is not certain whether daytime napping may have influenced the subjective estimates of sleep duration among older adults. It's likely that the survey question employed in NHANES may have been interpreted differently either as the time spent in bed or the time being asleep. Moreover, the interpretation might be affected by education level, which was significantly different between age groups. We should note, however, that our model adjusted for education level; we only considered adjusted risk estimates in all of analyses. Nonetheless, there are notable strengths to the study, including the use of a large representative sample of the US population, which provided adequate power to adjust effects of multiple confounders; this is often challenging with smaller sample sizes. Furthermore, our analyses employed Poisson regression modeling, which is a robust analytic tool to estimate population risks using binary data with adequate adjustments for known covariates.

5. Conclusions

Using NHANES data, we examined age-associated differences in sleep duration and the potential confounding effects of disease burden on these associations. Compared with their young counterparts, older adults (≥65 years) were not at increased risk for short sleep, which is often attributed to the presence of medical illnesses. Rather, they reported longer sleep time regardless of the presence of disease burden (i.e., obesity, diabetes, and hypertension) or differing sociodemographic factors. Future studies should investigate longitudinal effects of aging on objective sleep time, with or without the presence of varying diseases and potential buffers (e.g. coping strategies) older adults utilize to mitigate age-related changes in sleep patterns.

Author contribution

GJL conceptualized the study and oversaw all aspects of data analysis and interpretation. PJ, OMB, and EW processed and analyzed the data and contributed to data interpretation. PJ analyzed the data and prepared tables and figures. AS and OMB helped to develop the scientific arguments and contributed to data interpretation. AS, SY, TS, AQB contributed to the development of the scientific arguments, as well as the discussion and reviewed/edited the manuscript. All authors contributed to the content in the manuscript and approved the final version.

Statement of ethics

All procedures performed in this study involving human participants were completed in accordance with the ethical standards of the NYU Langone Health Institutional Review Board and with the Helsinki declaration and its amendments.

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Data availability

The dataset utilized for analyses of the current study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors have no conflicts of interest to declare.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.09.004.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2021.09.004.

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