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Sex and age differences in the associations between sleep behaviors and all-cause mortality in older adults: results from the National Health and Nutrition Examination Surveys

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Abstract

Objective—Our aim was to examine sex- and age-specific relationships of sleep behaviors with all-cause mortality rates.

Methods—A retrospective cohort study was conducted among 5288 adults (≥50 years) from the 2005–2008 National Health and Nutrition Examination Surveys who were followed-up for 54.9 ± 1.2 months. Sleep duration was categorized as < 7 h, 7—8 h and >8 h. Two sleep quality indices were generated through factor analyses. 'Help-seeking behavior for sleep problems' and 'diagnosis with sleep disorders' were defined as yes/no questions. Sociodemographic covariates-adjusted Cox regression models were applied to estimate hazard ratios (HRs) and 95% confidence intervals (CIs).

Results—A positive relationship was observed between long sleep and all-cause mortality rate in the overall sample (HR = 1.90, 95% CI: 1.38, 2.60), among males (HR = 1.48, 95% CI: 1.05, 2.09), females (HR = 2.32, 95% CI: 1.48, 3.61) and elderly (≥65 years) people (HR = 1.80, 95% CI: 1.30, 2.50). 'Sleepiness/sleep disturbance' (Factor I) and all-cause mortality rate were positively associated among males (HR = 1.22, 95% CI: 1.03,1.45), whereas 'poor sleep-related daytime dysfunction' (Factor II) and all-cause mortality (HR = 0.75, 95% CI: 0.62, 0.91) were negatively associated among elderly people.

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Appendix A. Supplementary data: Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.sleep.2017.05.006.

Conclusions—Sex- and age-specific relationships were observed between all-cause mortality rate and specific sleep behaviors among older adults.

Keywords

Age; Cohort study; Mortality; Sex; Sleep; Surveillance

1. Introduction

Sleep inadequacy is an emerging public health concern linked simultaneously to the obesity epidemic and population aging; estimates suggest one in five adults are affected by health problems related to sleep duration and quality [1–3]. A growing body of evidence has shown that (short or long) sleep duration [1,4–17], sleep disturbances [1,9,18] and obstructive sleep apnea (OSA) [19–26] may predict all-cause [1,9–19,21–25,27–31], cardiovascular- [1,4,10,13,16,17,19,24,29], cancer- [1,16,17,24,30] and dementia-specific [6] mortality rates. Although there are distinct definitions for sleep duration, most studies examining short [1,6,9–11,16] or long sleep [5,11,13,15,32] as risk factors for all-cause or cause-specific mortality rates have considered 7–8 h as the optimal range for sleep duration [33–36]. A recently published review identified 42 cohort studies that provided evidence for an inconsistently U-shaped relationship between sleep duration and mortality rate [14]. Specifically, a detrimental effect of short and long sleep was observed in some, but not all studies; also, study findings may have been affected by methodological issues of reverse causation, measurement, response and confounding biases [14].

The role of sleep disorders (such as OSA) and sleep disturbances (poor sleep quality) in predicting mortality rate is less clear-cut. Sleep disorders are a group of chronic conditions that manifest in difficulty initiating or maintaining sleep, as well as, non-restorative sleep [28,29,32,37]. OSA is a highly prevalent sleep disorder characterized by frequent episodes of upper-airway collapse during sleep [19,20,22,23,25]. If left untreated, moderate to severe OSA could lead to neurocognitive impairment, motor vehicle accidents, cardiovascular disease, cancer and death [3,29]. More broadly, experimental evidence has implicated sleep disturbances (poor sleep quality) in the slowing of biological restoration as well as the worsening of insulin sensitivity and glucose tolerance [1], suggesting a potential mediating role for hormonal factors and effect modification of sleep–mortality relationships by sex and age. To our knowledge, previously conducted studies have not explicitly examined effect modification of the hypothesized sleep–mortality relationships by sex or age. In this retrospective cohort study of older adults who participated in the 2005–2008 National Health and Nutrition Examination Surveys (NHANES), we examined sex-and age-specific relationships of sleep behaviors, namely sleep duration, quality and disorders, with all-cause mortality rates, taking a broad range of demographic, socioeconomic, lifestyle and health-related confounders into consideration.

2. Materials and methods

2.1. National health and nutrition examination surveys

The NHANES is a program of studies conducted by the National Center for Health Statistics, a division of the Centers for Disease Control and Prevention (CDC), to assess the health and nutritional status of US children and adults and to determine the prevalence of major diseases and their risk factors [38,39]. The NHANES uses stratified multistage cluster sampling with oversampling of African Americans, Asians, Hispanics and adults 60 years and older [38]. Demographic, socioeconomic and nutritional data were collected through in-person interviews, physical examinations and laboratory tests [38,39]. The original study was approved by an Institutional Review Board and all study participants provided informed consent.

2.2. Study participants

Since 1999, NHANES has become a continuous surveillance system. We selected 20,499 NHANES participants from two consecutive waves, namely 2005–2006 (N = 10,348) and 2007–2008 (N = 10,149). We excluded subjects who were <50 years of age (N = 15,211) or had missing data on sleep duration, help-seeking behavior for sleep problems or diagnosis with sleep disorders (N = 7814). The final sample consisted of 5288 adults of ≥50 years of age, who had no missing data on sleep duration, help-seeking behavior for sleep problems or diagnosis with sleep disorders.

2.3. Variable definitions

2.3.1. Sleep behaviors—Sleep-related measures and scales were included in the 2005–2008 NHANES data as part of a Computer-Assisted Personal Interview. The sleep questionnaire included items related to sleep duration, quality, disturbances and disorders. A subscale of eight questions, related to general productivity from the Functional Outcomes of Sleep Questionnaire [40] was also included. Sleep duration was assessed using one question ("How much sleep do you usually get at night on weekdays or workdays?") for which responses were analyzed as a categorical variable (short sleep: <7 h, normal sleep: 7–8 h, long sleep: >8 h) [41]. Of note, 35.9% reported <7 h (4.6% < 5 h; 31.2% 5–6 h), 56.4% reported 7–8 h and 7.7% reported >8 h of sleep. As previously described [42], we considered multiple NHANES questions for generating sleep quality indices. An exploratory factor analytic approach was used on 21 items from NHANES that were measured on a four-point or five-point Likert scale with higher scores reflecting worse sleep quality (Appendix A). Factors were extracted based on common variance, and factor loadings were estimated with residual variances labeled as uniqueness for each of the 21 items. This common factor model can be summarized as follows:

$$\mathrm{Item_i}=\sum_{j=1}^{k}\lambda_{ij}*\mathrm{Factor}_j+\phi_i$$

where $Item_i$ is the value of the item on a scale of 1–5, λ_{ij} is the factor loading for each item, $Factor_j$ is a standardized z-score for each factor j, and φ_i is the residual error. An eigenvalue >1 rule was used and the Scree plot was examined to determine the number of extracted factors that would produce the best model fit. The factor loadings were then rotated using Varimax orthogonal rotation. Factor loadings ≥0.40 were considered significant. Using the regression method, factor scores (z-scores) were predicted and used as markers of a specific domain of sleep quality, with higher scores indicating poorer sleep. Subsequently, items with weak factor loadings on all factors were deleted, yielding 15 items. A factor analysis of these 15 items was conducted. Two factors were extracted and rotated using Varimax orthogonal rotation, namely, Factor 1 ('Sleepiness and sleep disturbance') and Factor 2 ('Poor sleep-related daytime dysfunction') (Appendix B). Finally, help-seeking behavior for sleep problems ("Have you ever told a doctor or other health professionals that you have trouble sleeping?") and diagnosis with sleep disorders ("Have you ever been told by a doctor or other health professional that you have a sleep disorder?") were assessed as dichotomous (yes/no) variables.

2.3.2. All-cause mortality—Mortality linkage of the 2005–2008 NHANES with the National Death Index provides the opportunity to investigate associations of a wide range of characteristics at baseline with mortality rates at follow-up through December 31, 2011. Variables provided in this linked mortality file include sequence number, eligibility status, assigned vital status, mortality source, person-months of follow-up from interview date, person-months of follow-up from Mobile Examination Center (MEC) and underlying multiple causes of death [43]. In this analysis, an event was defined as death from any cause during the follow-up period, starting at date of MEC examination and ending before 31 December 2011. An estimated 9.8% of the study sample died during an average follow-up time of 54.9 ± 1.2 months.

2.3.3. Covariates—Selected personal characteristics were considered as a priori confounders or mediators for the hypothesized relationships between sleep behaviors and all-cause mortality, based on the literature [38,39,41,44–49]. These include demographic (sex (male, female), age group (50–54, 55–59, 60–64, 65–69, 70 + years), race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, other)), socioeconomic (education (less than high school, high school, more than high school), marital status (married, not married), poverty income ratio (PIR) (<1, 1 to <2, ≥2)), lifestyle (smoking status (current smoker, ex-smoker, never smoker), alcohol consumption (≥12 glasses in the past 12 months) (yes/no), moderate or vigorous physical activity (yes/no), the nutrient adequacy score (NAS) (range: 0–22) calculated as the sum of 22 nutrient components, with a higher score reflecting better overall nutrient adequacy, as described in a previously conducted study [50,51]] and health-related (body mass index (BMI) (<25,25 to <30, 30+ kg/m^2), waist circumference (high: ≥102 cm (40 in) in men or ≥88 cm (35 in) in women vs low: <102 cm (40 in) in men or <88 cm (35 in) in women) [52], high systolic or diastolic blood pressure (yes/no), self-rated health (excellent/very good/good, fair/poor), depressive symptoms based on the nine-item Patient Health Questionnaire (PHQ) total score (high: ≥10, low: <10) [53]) characteristics. Of note, sex (male vs female) and age group (50–64 vs 65 + years) were also examined as potential effect modifiers for the hypothesized relationships.

2.4. Statistical analysis

Statistical analyses were performed using STATA version 14 (STATA Corporation, College Station, TX). In order to maximize the use of the 2005–2008 NHANES data, multiple imputations (k = 5) were performed assuming sleep quality and covariate data were missing completely at random. Summary statistics included percentages (standard errors) for categorical variables as well as means (standard errors) for continuous variables. Linear, binary and multinomial logistic regression models were constructed to estimate the unstandardized slope coefficient (β) and odds ratios (ORs) with their 95% confidence intervals (CIs) for bivariate relationships of sleep behaviors with covariates. Cox regression was used to estimate hazard ratios (HRs) and 95% CI for predictors of all-cause mortality, in unadjusted (Model I), partially adjusted (Model II: demographic and socioeconomic covariates), and fully adjusted (Model III: demographic, socioeconomic, lifestyle and health covariates) models. Models II and III were constructed in order to distinguish between factors that are clearly confounders from factors that may also mediate the hypothesized relationships. We also evaluated effect modification by including interaction terms of sleep behaviors with sex or age group in partially and fully adjusted models. Sensitivity analyses were also conducted to evaluate whether self-identified race/ethnicity defined as 'White' vs 'non-White' and duration of follow-up defined as a dichotomous variable taking average value as the cut-off point (<55 months vs ≥55 months) modified the hypothesized relationships between sleep behaviors and all-cause mortality. Sampling weights were used to produce correct population estimates accounting for differential probabilities of selection and adjusting for non-coverage, non-response and oversampling of subpopulations. Two-sided statistical tests were performed whereby $p < 0.05$ was considered significant for most analyses.

3. Results

Demographic, socioeconomic, lifestyle and health-related characteristics of the study sample are described and examined in relation to all-cause mortality rate in Table 1. The study sample consisted of 5288 2005–2008 NHANES participants, with mean (standard error) age of 63.4 (0.3) years, of whom 54% were female, 78% were White, 52% had above high school education, 63% were married and 64% were at least 200% above the poverty line; also, 48% were never smokers, 68% consumed alcohol in the past 12 months, 59% performed moderate to vigorous physical activity, with mean (standard error) NAS estimated at 10.2 (0.09). Moreover, 36% had BMI ≥30 kg/m^2, 60% had high waist circumference, 68% had high systolic or diastolic blood pressures, 22% had fair or poor self-rated health and 6% had a depression score ≥10. Elderly (65+ years), unmarried, physically inactive people, those who did not consume alcohol in the past 12 months, those with high blood pressure and those who reported fair/poor self-rated health experienced higher all-cause mortality rates. Increasing NAS as well as ≥ high school education were inversely related to all-cause mortality rate. Interestingly, no significant relationship was observed between sex and all-cause mortality rate and BMI ≥25 kg/m^2 predicted lower all-cause mortality rate.

Table 2 presents demographic, socioeconomic, lifestyle and health-related predictors of sleep duration, disturbances and disorders. As expected, short/long sleep were less

frequently observed in the context of higher socioeconomic status, based on education and PIR. Also, an inverse relationship was observed between higher NAS and suboptimal sleep duration. Female sex, age ≥65 years, unmarried status, moderate to vigorous physical activity, high blood pressure and fair/poor self-rated health positively correlated with long sleep. Furthermore, non-White race, unmarried status, consumption of alcohol, moderate or vigorous physical activity, BMI ≥30 kg/m^2, fair/poor self-rated health and depression score ≥10 positively correlated with short sleep. Ex-smokers and never-smokers were less likely than others to be short sleepers. Whereas female sex was directly related to help-seeking behavior for sleep problems, it was inversely related to diagnosis with sleep disorders. In addition, unmarried status, fair/poor self-rated health and depression score ≥10 was directly related and Hispanic ethnicity was inversely related to help-seeking behavior for sleep problems. Diagnosis with sleep disorders was directly related to fair/poor self-rated health as well as depression score ≥10 and less frequent among those aged ≥70 years. As expected, both help-seeking behavior for sleep problems and sleep disorders were increased among individuals with BMI ≥30 kg/m^2 and high waist circumference, and decreased among individuals who consumed alcohol in the past 12 months.

Demographic, socioeconomic, lifestyle and health-related predictors of sleep quality factors are displayed in Table 3. A direct relationship was identified between female sex and Factor I (‘sleepiness/sleep disturbance’), but not Factor II (‘Poor sleep-related daytime dysfunction’). Whereas Factor I was inversely related to age ≥65 years, Black race, PIR >2 and higher NAS, Factor II was lower among never-smokers and individuals ≥60 years of age. Furthermore, Factor I positively correlated with alcohol consumption in the past 12 months as well as moderate to vigorous physical activity and Factor II positively correlated with BMI ≥30 kg/m^2. Finally, both Factors I and II were directly associated with fair/poor self-rated health and depression score ≥10.

Table 4 presents unadjusted, fully adjusted and partially adjusted Cox regression models for sleep behaviors as predictors of all-cause mortality rate, before and after stratifying to sex and age group. Overall, short and long sleep durations were associated with higher all-cause mortality rate in the unadjusted model, but not in the fully adjusted model. In partially adjusted models, a positive relationship was observed between long sleep and all-cause mortality rate in the overall sample (HR = 1.90, 95% CI: 1.38, 2.60), among males (HR = 1.48, 95% CI: 1.05, 2.09), females (HR = 2.32, 95% CI: 1.48, 3.61) and elderly (≥65 years) people (HR = 1.80, 95% CI: 1.30,2.50). ‘Sleepiness/sleep disturbance’ (Factor I) and all-cause mortality rate were positively associated among males (HR = 1.22, 95% CI: 1.03, 1.45), whereas ‘poor sleep-related daytime dysfunction’ (Factor II) and all-cause mortality (HR = 0.75, 95% CI: 0.62, 0.91) were negatively associated among elderly people. These relationships became statistically non-significant after adjustments for lifestyle and health characteristics. Help-seeking behavior for sleep problems and diagnosis with sleep disorders were not significantly related to all-cause mortality risk, in the unadjusted, fully adjusted or partially adjusted models. Sensitivity analyses suggested that, for the most part, race/ethnicity and duration of follow-up did not modify the hypothesized relationships between sleep behaviors and all-cause mortality. One exception is the observed statistical interaction between race/ethnicity and hours of sleep. Specifically, all-cause mortality was less strongly associated with long hours of sleep among individuals who self-identify as White (HR =

1.04, 95% CI: 0.59, 1.81) as compared to individuals who self-identify as non-White (HR = 2.59, 95% CI: 1.40, 4.76) in the fully adjusted model ($p_{interaction}$ = 0.014).

4. Discussion

In this retrospective cohort study of 5288 adults (≥50 years of age) who participated in the 2005–2008 NHANES and were followed-up for an average of 54.9 months through linkage with the National Death Index until 31 December 2011, we examined sex- and age-specific relationships of sleep behaviors, namely sleep duration, quality and disorders, with all-cause mortality rates, taking a broad range of demographic, socioeconomic, lifestyle and health-related confounders into consideration. Our results suggested that help-seeking behavior for sleep problems and diagnosis with sleep disorders were not significantly related to all-cause mortality rate. In contrast, sex- and age-specific relationships were observed for sleep duration and sleep quality. Specifically, a positive association was observed between long sleep and all-cause mortality rate in the overall sample as well as among males, females and elderly (≥65 years) people, after adjustment for demographic and socioeconomic factors. Similarly, a positive association between ‘sleepiness/sleep disturbance’ and all-cause mortality rate among males and a negative association between ‘poor sleep-related daytime dysfunction’ and all-cause mortality rate among elderly (≥65 years) people were observed after adjustment for demographic and socioeconomic factors. Sensitivity analyses revealed a stronger all-cause mortality risk in the context of prolonged sleep – but no other sleep behaviors – among non-White versus White populations.

Our results are partly consistent with the published literature that has identified sleep duration [1,4–17], sleep disturbances [1,9,18] and OSA [19–26] as predictors of mortality rates. We found long (but not short) sleep duration and ‘sleepiness/sleep disturbance’ – a measure of sleep quality – to be sex- and age-specific risk factors for all-cause mortality. An interesting finding is the protective nature of the relationship between ‘poor sleep-related daytime dysfunction’ and all-cause mortality in elderly (≥65 years) people. These associations could be confounded or mediated by lifestyle and health characteristics, since they were no longer significant after adjustment for these covariates. Alternatively, sleep behaviors may be considered as markers for lifestyle and health risk factors for infectious/chronic diseases or injuries that are the leading causes of death. Previous studies have shown that subjective sleep quality is actually higher among older adults compared to younger adults, after adjusting for confounders, and this seems to be especially the case for daytime tiredness/fatigue. For instance, a study using the Behavioral Risk Factor Surveillance System (BRFSS) showed that daytime fatigue in older adults is completely explained by poor health and depression [54]. Thus, the finding that the relationship of ‘poor sleep-related daytime dysfunction’ with all-cause mortality is mediated by these factors is not surprising.

Increased risk of dying from prolonged sleep has been reported in older adults, with several biological mechanisms proposed, including sleep fragmentation, fatigue, depression and inactivity [7,55]. On the other hand, short sleep has been linked with several leading causes of death including obesity, diabetes, hypertension, cardiovascular disease and cancer [56]. The mechanisms supportive of the obesogenic effects of short sleep and sleep disturbance include upregulation of appetite, increased time to eat, lower energy expenditure, and altered

glucose metabolism. Short sleep can reduce leptin and elevate ghrelin, which may culminate in a powerful stimulus to food intake and can ultimately lead to obesity and diabetes [57]. Other metabolic hormones have also been implicated including cortisol, insulin and growth hormone [58,59]. Short sleep and sleep disturbance may impact on adaptive and innate immunity including antiviral immune responses with consequences for infectious disease and pro-inflammatory immune responses with implications for cardiovascular disease and cancer [60]. Sleep disturbance has been reported to be related to heightened systemic inflammation [61]. Systemic inflammation is considered as a potential mechanism for the association between sleep disturbance and mortality. Sleep disturbance may act as a stressor that can increase the activity of the neuroendocrine stress systems including the hypothalamic–pituitary–adrenal axis and autonomic sympatho-adrenal axis and the reactivity of these systems to other stressors [62]. Chronic activation of these neuroendocrine systems may lead to neuronal damage, earlier aging, and mortality [63]. It is worth noting that previously conducted studies have examined the relationship of sleep with obesity [64–66], diabetes [41,64,67,68], heart disease [69], depression [70–72], cholesterol [73,74] and inflammation [75] using NHANES data.

Limited evidence precludes us from drawing conclusions pertaining to sleep quality and disorders as predictors of all-cause mortality rate. In a longitudinal study of 1741 men and women randomly selected from Central Pennsylvania (Penn State Cohort), all-cause mortality was higher among men (but not women) who simultaneously experienced insomnia and short sleep (<6 h) [76]. By contrast, evidence supporting a link between sleep duration and all-cause mortality rate is substantial. Our findings are in line with recent studies showing that there was indeed an association between sleep duration and all-cause mortality rate [11,77,78]. Among several cohort studies, a study of 2256 Mexican-American older adults aged ≥65 years (Hispanic EPESE) found that having sleep problems during the last month was associated with increased risk in mortality by 14%, an association that was attenuated when other covariates were included in the model [27]. A study using the Health Aging and Body Composition cohort study recently found that among older adults recruited from Medicare listings, baseline subjective short sleep duration was associated with mortality rate, an effect that was partly mediated through inflammatory markers. Those markers did not attenuate the positive association also found between long sleep duration and mortality [11]. A 30-year follow-up study of 5249 men (40–59 years old at baseline) suggested that sleeping for less than 6 h per day increased the risk of ischemic heart disease but not all-cause mortality, taking medium sleepers as the reference (6–7 h of sleep). This relationship was stronger among those using tranquilizers and hypnotics [10]. In one of the largest cohort studies examining sleep duration in relation to mortality thus far, a total of 113,138 participants of both sex groups were recruited in the Shanghai Women's and Men's Health Studies [6]. The study concluded that there was a J-shaped pattern between sleep duration and all-cause as well as cause-specific mortality rates [6]. In particular, both shorter and longer sleep durations were independently associated with increased mortality rate. However, longer sleep was linked to higher mortality rate from cardiovascular and diabetes causes than shorter sleep [6].

Taking the body of evidence into consideration, the current study exhibits several strengths. First, it is based on a large population-based cohort from the nationally representative study

sample. Second, it explicitly examined the potential effect-modifying roles of sex and age. Third, many of the previously conducted cohort studies were limited by selection bias for including an older population than the NHANES, whereas this study has better external validity than prior studies. Fourth, objective measures were used for clinical characteristics selected as potential confounders, including weight and height, waist circumference, systolic and diastolic blood pressure. Finally, sleep indices generated by factor analysis account for a large proportion of the variance in the models predicting all-cause mortality, suggesting an improvement in the validity of the sleep construct compared with other survey-based studies on this topic.

Our results should be carefully interpreted in light of study limitations. First, sample size precluded further analyses pertaining to cause-specific mortality rate as well as effect modification by a more granular definition of race/ethnicity. Second, there is a potential for selection bias due to missing data and a relatively short duration of follow-up which may have influenced the distribution by cause of death. In particular, less healthy subjects and those dying accidentally are more likely to have been captured than those with chronic conditions. Third, no objective measures of sleep parameters but rather self-reported measures were used in the 2005–2008 NHANES data; thus, non-differential misclassification will likely bias estimated measures of association toward the null value. In particular, it may not be possible to distinguish subjects with sleep disorders such as insomnia or sleep apnea from those without sleep disorders based on self-reported measures from the 2005–2008 NHANES data. Although we included many covariates in the models, residual confounding is likely because of unmeasured confounders such as other comorbidities, psychosocial stress, family history of cardiovascular disease, cancer and other chronic conditions as well as work schedule (ie, shift work).

5. Conclusions

In conclusion, this population-based retrospective cohort study showed that all-cause mortality rate was positively associated with ‘sleepiness/sleep disturbance’ among males, after controlling for demographic and socioeconomic factors. In elderly people, long sleep was positively associated whereas ‘poor sleep-related daytime dysfunction’ was negatively associated with all-cause mortality rate, after controlling for demographic and socioeconomic factors. These findings highlight the need for risk stratification when examining health risks associated with sleep behaviors. Large prospective cohort studies are needed to elucidate these complex relationships in diverse populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Demographic, socioeconomic, lifestyle and health-related predictors of all-cause mortality rates: National Health & Nutrition Examination Surveys 2005–2008 (*N* = 5288).

	% (SEM) or mean (SEM)	HR	95% CI	*p*
Deaths	9.8 (0.6)			
Follow-up time (months)	54.9 (1.2)			
Sex				
Male	46.1 (0.7)	Ref.	–	–
Female	53.9 (0.7)	0.87	0.74, 1.02	0.083
Age (years)				
Mean ± SEM	63.4 (0.3)			
50–54	25.4 (1.3)	Ref.	–	–
55–59	18.2 (0.7)	1.49	0.63, 3.54	0.35
60–64	15.3 (0.6)	1.75	0.83, 3.69	0.13
65–69	12.3 (0.6)	2.92	1.48, 5.75	0.003
70+	28.8 (1.1)	10.7	5.64, 17.99	<0.0001
Race/ethnicity				
Non-Hispanic White	78.1 (2.2)	Ref.	–	–
Non-Hispanic Black	9.7 (1.4)	1.25	1.00, 1.55	0.053
Hispanic	7.2 (0.9)	0.70	0.49, 1.01	0.052
Other	4.9 (0.7)	0.68	0.32, 1.42	0.28
Education				
<HS	20.9 (1.2)	Ref.	–	–
HS	27.3 (9.9)	0.62	0.51, 0.75	<0.0001
>HS	51.8 (1.8)	0.40	0.30, 0.52	<0.0001
Marital status				
Married	62.8 (1.4)	Ref.	–	–
Not married	37.2 (1.4)	2.18	1.86, 2.56	<0.0001
Poverty–income ratio				
<1	15.2 (0.9)	Ref.	–	–
1 to <2	20.2 (0.9)	1.13	0.88, 1.45	0.34
2+	64.4 (1.4)	0.45	0.36, 0.58	<0.0001
Smoking status				
Current smoker	16.9 (0.9)	Ref.	–	–
Ex-smoker	35.4 (0.9)	1.13	0.82, 1.55	0.45
Never smoker	47.7 (1.2)	0.81	0.64, 1.02	0.084
Alcohol consumption (past 12 months)				
Yes	67.6 (1.6)	Ref.	–	–
No	32.4 (1.6)	1.52	1.20, 1.93	0.004
Physical activity (moderate or vigorous)				
Yes	9.3 (1.9)	Ref.	–	–
No	40.7 (1.9)	2.44	1.81, 3.27	<0.0001

	% (SEM) or mean (SEM)	HR	95% CI	*p*
Body mass index (kg/m^2)				
<25	28.9 (0.9)	Ref.	–	–
25 to <30	34.9 (0.8)	0.64	0.50, 0.83	0.002
30+	36.1 (0.9)	0.52	0.39, 0.69	<0.0001
Waist circumference (cm)[a]				
High	60.3 (0.9)	Ref.	–	–
Low	39.7 (0.9)	1.79	1.48, 2.15	<0.0001
Systolic blood pressure (mm Hg)	130.6 (0.5)	1.01	1.01, 1.02	<0.0001
Diastolic blood pressure (mm Hg)	70.9 (0.3)	0.97	0.96, 0.98	<0.0001
High blood pressure				
Yes	67.8 (1.2)	1.48	1.09, 2.01	0.02
No	32.2 (1.2)	Ref.	–	–
Self-rated health				
Excellent/very good/good	78.3 (1.0)	Ref.	–	–
Fair/poor	21.7 (1.1)	2.72	2.09, 3.54	<0.0001
Depression				
Mean ± SEM	2.8 (0.1)	1.03	1.00, 1.06	0.05
≥10	6.4 (0.5)	1.13	0.77, 1.64	0.51
<10	93.6 (0.5)	Ref.	–	–
Nutrient adequacy score	10.2 (0.09)	0.93	0.89, 0.98	0.009

CI, confidence interval; HR, hazard ratio; HS, high school; SEM, standard error of the mean.

[a]Waist circumference (high, ≥102 cm (40 in) in men or ≥88 cm (35 in) in women; low, <102 cm (40 in) in men or <88 cm (35 in) in women).

Table 2

Demographic, socioeconomic, lifestyle and health-related predictors of sleep duration, disturbances and disorders: National Health & Nutrition Examination Surveys 2005–2008.

	Sleep duration (h)			Ever told doctor you had trouble sleeping	Ever told by doctor you had a sleep disorder
	<7 OR (95% CI) *p*	7–8	>8 OR (95% CI) *p*	OR (95% CI) *p*	OR (95% CI) *p*
Sex		Ref.			
Male	Ref.		Ref.	Ref.	Ref.
Female	1.03 (0.89, 1.21) 0.66		1.62 (1.22, 2.14) 0.001	1.68 (1.38, 2.05) <0.0001	0.71 (0.52, 0.96) 0.030
Age (years)		Ref.			
50–54	Ref.		Ref.	Ref.	Ref.
55–59	1.09 (0.81, 1.45) 0.57		0.71 (0.31, 1.62) 0.40	1.21 (0.89, 1.68) 0.22	1.06 (0.75, 1.49) 0.73
60–64	0.80 (0.64, 1.01) 0.056		1.20 (0.62, 2.34) 0.58	0.91 (0.70, 1.20) 0.50	0.89 (0.59, 1.35) 0.57
65–69	0.79 (0.55, 1.12) 0.17		2.20 (1.38, 3.53) 0.002	0.84 (0.65, 1.10) 0.19	0.88 (0.61, 1.25) 0.45
70+	0.84 (0.65, 1.06) 0.14		3.46 (2.01, 5.99) <0.0001	0.90 (0.73, 1.12) 0.30	0.68 (0.50, 0.91) 0.011
Race		Ref.			
White	Ref.		Ref.	Ref.	Ref.
Black	2.48 (2.10, 2.94) <0.0001		1.35 (0.93, 1.95) 0.11	0.99 (0.84, 1.17) 0.94	1.01 (0.75, 1.35) 0.96
Hispanic	1.46 (1.17, 1.84) 0.002		0.97 (0.72, 1.31) 0.84	0.61 (0.46, 0.80) 0.001	0.90 (0.63, 1.25) 0.48
Other	1.90 (1.28, 2.80) 0.002		0.51 (0.20, 1.26) 0.14	1.13 (0.78, 1.67) 0.51	1.06 (0.53, 2.14) 0.86
Education		Ref.			
<HS	Ref.		Ref.	Ref.	Ref.
HS	0.83 (0.68, 1.01) 0.058		0.48 (0.31, 0.75) 0.002	1.02 (0.84, 1.25) 0.84	1.00 (0.68, 1.48) 0.98
>HS	0.68 (0.56, 0.84) <0.0001		0.25 (0.20, 0.31) <0.0001	1.14 (0.97, 1.34) 0.11	1.28 (0.91, 1.84) 0.14
Marital status		Ref.			
Married	Ref.		Ref.	Ref.	Ref.
Not married	1.43 (1.25, 1.67) <0.0001		1.67 (1.31, 2.12) <0.0001	1.16 (1.01, 1.36) 0.040	0.79 (0.61, 1.03) 0.077
Poverty–income ratio		Ref.			
<1	Ref.		Ref.	Ref.	Ref.
1 to <2	0.81 (0.64, 1.03) 0.09		1.15 (0.76, 1.73) 0.51	0.93 (0.76, 1.14) 0.44	0.70 (0.51, 0.97) 0.033
2+	0.65 (0.54, 0.79) <0.0001		0.52 (0.39, 0.71) <0.0001	0.90 (0.73, 1.12) 0.32	0.75 (0.55, 1.02) 0.062

	Sleep duration (h)			Ever told doctor you had trouble sleeping	Ever told by doctor you had a sleep disorder
	<7 OR (95% CI) *p*	**7–8**	**>8 OR (95% CI) *p***	**OR (95% CI) *p***	**OR (95% CI) *p***
Smoking status		Ref.			
Current smoker	Ref.		Ref.	Ref.	Ref.
Ex-smoker	0.063 (0.51, 0.79) <0.0001		0.85 (0.57, 1.27) 0.43	0.97 (0.75, 1.27) 0.84	1.30 (0.87, 1.95) 0.19
Never smoker	0.68 (0.53, 0.85) 0.002		0.86 (0.55, 1.34) 0.48	0.39 (0.36, 0.43) 0.30	1.07 (0.76, 1.51) 0.69
Alcohol consumption (past 12 months)		Ref.			
Yes	1.19 (1.00, 1.39) 0.045		1.26 (0.94, 1.68) 0.11	0.39 (0.36, 0.43) 0.016	0.09 (0.08, 0.11) 0.001
No	Ref.		Ref.	Ref.	Ref.
Physical activity (moderate or vigorous)					
Yes	Ref.		Ref.	Ref.	Ref.
No	1.48 (1.15, 1.86) 0.004		2.34 (1.72, 3.19) <0.0001	1.07 (0.79, 1.43) 0.65	1.10 (0.68, 1.77) 0.67
Nutrient adequacy score	0.93 (0.91, 0.95) <0.0001		0.94 (0.90, 0.98) 0.008	0.99 (0.97, 1.02) 0.63	0.99 (0.95, 1.04) 0.76
Body mass index (kg/m^2)		Ref.			
<25	Ref.		Ref.	Ref.	Ref.
25 to <30	1.20 (0.97, 1.48) 0.086		0.81 (0.61, 1.07) 0.13	0.90 (0.75, 1.09) 0.28	1.46 (0.94, 2.29) 0.093
30+	1.39 (1.17, 1.65) 0.001		0.76 (0.57, 1.00) 0.052	1.25 (1.02, 1.54) 0.033	3.46 (2.41, 5.00) <0.0001
Waist circumference (cm)[a]		Ref.			
High	Ref.		Ref.	Ref.	Ref.
Low	0.84 (0.71, 0.99) 0.042		1.21 (1.00, 1.46) 0.056	0.74 (0.63, 0.88) 0.001	0.49 (0.34, 0.70) <0.0001
High blood pressure		Ref.			
Yes	1.08 (0.89, 1.32) 0.43		1.52 (1.07, 2.16) 0.025	0.96 (0.75, 1.23) 0.72	0.93 (0.73, 1.19) 0.53
No	Ref.		Ref.	Ref.	Ref.
Self-rated health		Ref.			
Excellent/very good/good	Ref.		Ref.	Ref.	Ref.
Fair/poor	1.93 (1.63, 2.32) <0.0001		1.80 (1.39, 2.36) <0.0001	1.97 (1.60, 2.41) <0.0001	2.03 (1.51, 2.75) <0.0001
Depression		Ref.			
<10	Ref.	Ref.	Ref.	Ref.	Ref.
≥10	2.80 (2.01, 3.90) <0.0001		1.13 (0.58, 2.20) 0.72	4.71 (3.60, 6.17) <0.0001	3.74 (2.61, 5.31) <0.0001

CI, confidence interval; HR, hazard ratio; OR, Odds Ratio.

[a]Waist circumference (high, ≥102 cm (40 in) in men or ≥88 cm (35 in) in women; low, <102 cm (40 in) in men or <88 cm (35 in) in women).

Table 3

Demographic, socioeconomic, lifestyle and health-related predictors of sleep quality factors: National Health & Nutrition Examination Surveys 2005–2008.

	Sleep quality factors	
	Factor I: 'sleepiness/sleep disturbance' β (95% CI) *p*	**Factor II: 'Poor sleep-related daytime dysfunction' β (95% CI) *p***
Sex		
Male	Ref.	Ref.
Female	0.24 (0.17, 0.32) <0.0001	−0.052 (-0.13, 0.023) 0.17
Age (years)		
50–54	Ref.	Ref.
55–59	−0.021 (-0.12, 0.076) 0.66	−0.11 (-0.24, 0.018) 0.088
60–64	−0.071 (-0.16, 0.017) 0.11	−0.21 (-0.31, −0.11) <0.0001
65–69	−0.17 (-0.27, −0.063) 0.003	−0.27 (-0.37, −0.17) <0.0001
70+	−0.17 (-0.25, −0.089) <0.0001	−0.43 (-0.51, −0.36) <0.0001
Race		
White	Ref.	Ref.
Black	−0.082 (-0.16, −0.0025) 0.044	0.032 (-0.045, 0.11) 0.40
Hispanic	−0.065 (-0.14, 0.014) 0.099	−0.0050 (-0.084, 0.074) 0.89
Other	0.045 (-0.13, 0.22) 0.59	0.019 (-0.16, 0.19) 0.82
Education		
<HS	Ref.	Ref.
HS	0.085 (-0.011, 0.18) 0.080	0.069 (-0.053, 0.19) 0.26
>HS	−0.034 (-0.12, 0.054) 0.44	0.12 (-0.0085, 0.24) 0.07
Marital status		
Married	Ref.	Ref.
Not married	0.048 (-0.022, 0.12) 0.17	−0.0086 (-0.086, 0.069) 0.82
Poverty–income ratio		
<1	Ref.	Ref.
1 to <2	−0.11 (-0.24, 0.018) 0.089	−0.098 (-0.20, 0.049) 0.061
2+	−0.15 (-0.26, −0.043) 0.009	−0.051 (-0.17, 0.066) 0.36
	Smoking status	
Current smoker	Ref.	Ref.
Ex-smoker	−0.10 (-0.23, 0.024) 0.11	−0.11 (-0.24, 0.0061) 0.062
Never smoker	−0.078 (-0.17, 0.016) 0.11	−0.12 (-0.22, −0.012) 0.031
Alcohol consumption (past 12 months)		
Yes	0.072 (0.0019, 0.14) 0.044	0.0037 (-0.078, 0.086) 0.10
No	Ref.	Ref.
Physical activity (moderate or vigorous)		
Yes	Ref.	Ref.
No	0.13 (0.017, 0.24) 0.03	−0.062 (-0.15, 0.036) 0.19
Nutrient adequacy score	−0.013 (-0.022, −0.0027) 0.015	0.0041 (-0.0075, 0.016) 0.46

	Sleep quality factors	
	Factor I: 'sleepiness/sleep disturbance' β (95% CI) *p*	**Factor II: 'Poor sleep-related daytime dysfunction' β (95% CI) *p***
Body mass index (kg/m^2)		
<25	Ref.	Ref.
25 to <30	−0.053 (-0.15, 0.044) 0.25	0.032 (-0.033, 0.096) 0.32
30+	0.049 (-0.036, 0.13) 0.25	0.13 (0.033, 0.22) 0.010
Waist circumference (cm)[a]		
High	Ref.	Ref.
Low	−0.077 (-0.16, 0.007) 0.070	−0.074 (-0.15, 0.00027) 0.051
High blood pressure		
Yes	−0.033 (-0.11, 0.044) 0.38	−0.053 (-0.11, 0.0066) 0.078
No	Ref.	Ref.
Self-rated health		
Excellent/very good/good	Ref.	Ref.
Fair/poor	0.44 (0.35, 0.53) <0.0001	0.14 (0.057, 0.24) 0.003
Depression		
≥10	1.04 (0.93, 1.15) <0.0001	0.86 (0.63, 1.09) <0.0001
<10	Ref.	Ref.

Abbreviations: β, unstandardized slope coefficient; CI, confidence interval; HS, high school.

[a]Waist circumference (high, ≥102 cm (40 in) in men or ≥88 cm (35 in) in women; low, <102 cm (40 in) in men or <88 cm (35 in) in women).

Table 4

Sleep behaviors as a predictor of all-cause mortality rates, overall and according to sex and age groups: National Health & Nutrition Examination Surveys 2005–2008.

	Unadjusted		Fully adjusted[a]		Partially adjusted[a]	
	HR	**(95% CI) *p***	**HR**	**(95% CI) *p***	**HR**	**(95% CI) *p***
Overall						
Sleep duration (h)[b]						
<7	1.23	(1.00, 1.52) 0.043	1.10	(0.84, 1.43) 0.47	1.19	(0.96, 1.46) 0.11
7–8	Ref.		Ref.		Ref.	
>8	2.97	(2.30, 3.84) <0.0001	1.28	(0.75, 2.20) 0.33	1.90	(1.38, 2.60) <0.0001
Sleep quality indices×						
Factor I: ‘sleepiness/sleep disturbance’	1.04	(0.92, 1.17) 0.55	1.13	(0.95, 1.34) 0.16	1.11	(0.98, 1.24) 0.084
Factor II: ‘Poor sleep-related daytime dysfunction’	0.59	(0.48, 0.74) <0.0001	0.87	(0.64, 1.17) 0.31	0.78	(0.64, 0.95) 0.017
Ever told doctor you had trouble sleeping[c]						
Yes	0.92	(0.78, 1.09) 0.34	0.96	(0.71, 1.31) 0.81	1.02	(0.85, 1.21) 0.83
No	Ref.		Ref.		Ref.	
Ever told by doctor you had a sleep disorder[d]						
Yes	0.99	(0.69, 1.43) 0.97	1.42	(0.72, 2.81) 0.11	0.85	(0.59, 1.24) 0.40
No	Ref.		Ref.		Ref.	
Males						
Sleep duration (h)						
<7	1.13	(0.88, 1.44) 0.31	2.20	(1.65, 2.94) 0.57	1.17	(0.94, 1.47) 0.16
7–8	Ref.		Ref.		Ref.	
>8	2.69	(1.91, 3.80) <0.0001	1.55	(0.93, 2.59) 0.090	1.48	(1.05, 2.09) 0.026
Sleep quality indices						
Factor I: ‘sleepiness/sleep disturbance’	1.15	(0.97, 1.36) 0.099	1.30	(0.92, 1.83) 0.11	1.22	(1.03, 1.45) 0.026
Factor II: ‘Poor sleep-related daytime dysfunction’	0.59	(0.44, 0.79) 0.001	0.76	(0.52, 1.11) 0.14	0.80	(0.62, 1.03) 0.083
Ever told doctor you had trouble sleeping						
Yes	1.16	(0.84, 1.61) 0.34	1.10	(0.73, 1.64) 0.63	0.88	(0.65, 1.19) 0.39
No	Ref.		Ref.		Ref.	
Ever told by doctor you had a sleep disorder						

	Unadjusted		Fully adjusted[a]		Partially adjusted[a]	
	HR	**(95% CI) *p***	**HR**	**(95% CI) *p***	**HR**	**(95% CI) *p***
Yes	1.21	(0.73, 2.01) 0.45	1.55	(0.91, 2.65) 0.096	0.73	(0.46, 1.16) 0.16
No	Ref.		Ref.		Ref.	
Females						
Sleep duration (h)						
<7	1.36	(1.02, 1.82) 0.037	1.07	(0.67, 1.70) 0.77	1.22	(0.88, 1.69) 0.21
7–8	Ref.		Ref.		Ref.	
>8	3.35	(2.42, 4.64) <0.0001	1.14	(0.55, 2.38) 0.71	2.32	(1.48, 3.61) 0.001
Sleep quality indices						
Factor I: ‘Sleepiness/sleep disturbance’	0.96	(0.79, 1.17) 0.69	1.01	(0.71, 1.43) 0.94	1.03	(0.87, 1.22) 0.70
Factor II: ‘Poor sleep-related daytime dysfunction’	0.58	(0.43, 0.79) 0.002	0.97	(0.65, 1.46) 0.88	0.77	(0.57, 1.04) 0.073
Ever told doctor you had trouble sleeping						
Yes	0.79	(0.62, 1.01) 0.059	0.88	(0.63, 1.22) 0.41	1.15	(0.90, 1.48) 0.25
No	Ref.		Ref.		Ref.	
Ever told by doctor you had a sleep disorder						
Yes	0.72	(0.39, 1.32) 0.27	1.03	(0.34, 3.12) 0.96	1.06	(0.53, 2.11) 0.86
No	Ref.		Ref.		Ref.	
50–64 years						
Sleep duration (h)						
<7	1.65	(1.12, 2.44) 0.014	1.63	(0.95, 2.82) 0.072	1.39	(0.90, 2.16) 0.13
7–8	Ref.		Ref.		Ref.	
>8	2.66	(1.17, 6.08) 0.020	0.72	(0.17, 3.10) 0.64	1.92	(0.78, 4.69) 0.14
Sleep quality indices						
Factor I: ‘Sleepiness/sleep disturbance’	1.22	(0.86, 1.73) 0.24	1.21	(0.66, 2.23) 0.51	1.19	(0.85, 1.65) 0.31
Factor II: ‘Poor sleep-related daytime dysfunction’	0.85	(0.52, 1.39) 0.51	0.90	(0.47, 1.70) 0.71	0.85	(0.55, 1.31) 0.45
Ever told doctor you had trouble sleeping						
Yes	1.25	(0.83, 1.87) 0.27	1.62	(0.65, 3.99) 0.27	0.79	(0.50, 1.23) 0.27
No	Ref.		Ref.		Ref.	
Ever told by doctor you had a sleep disorder						
Yes	1.48	(0.67, 3.27) 0.32	0.70	(0.19, 2.55) 0.56	0.69	(0.30, 1.62) 0.38
No	Ref.		Ref.		Ref.	

	Unadjusted		Fully adjusted[a]		Partially adjusted[a]	
	HR	**(95% CI) *p***	**HR**	**(95% CI) *p***	**HR**	**(95% CI) *p***
65+ years						
Sleep duration (h)						
<7	1.20	(0.94, 1.52) 0.14	0.96	(0.68, 1.35) 0.80	1.12	(0.87, 1.43) 0.39
7–8	Ref.		Ref.		Ref.	
>8	1.90	(1.44, 2.50) <0.0001	1.30	(0.73, 2.29) 0.34	1.80	(1.30, 2.50) 0.001
Sleep quality indices						
Factor I: ‘Sleepiness/sleep disturbance’	1.08	(0.94, 1.23) 0.25	1.13	(0.91, 1.40) 0.25	1.08	(0.94, 1.25) 0.28
Factor II: ‘Poor sleep-related daytime dysfunction’	0.69	(0.57, 0.84) 0.001	0.86	(0.63, 1.17) 0.29	0.75	(0.62, 0.91) 0.005
Ever told doctor you had trouble sleeping						
Yes	0.93	(0.75, 1.15) 0.48	0.84	(0.55, 1.29) 0.39	1.12	(0.88, 1.41) 0.36
No	Ref.		Ref.		Ref.	
Ever told by doctor you had a sleep disorder						
Yes	0.99	(0.67, 1.44) 0.94	1.52	(0.93, 2.48) 0.084	0.96	(0.64, 1.43) 0.82
No	Ref.		Ref.		Ref.	

CI, confidence interval; HR, hazard ratio.

[a]Fully adjusted model includes sex, age group, race/ethnicity, education, marital status, poverty income ratio, smoking status, alcohol consumption (≥12 glasses in the past 12 months), moderate or vigorous physical activity, body mass index, waist circumference, high systolic or diastolic blood pressure, self-rated health, depressive symptoms and the nutrient adequacy score; Partially adjusted model includes sex, age group, race/ethnicity, education, marital status and poverty income ratio.

[b]Short sleep and age group (65+ years) have interaction effect ($p = 0.074$) of borderline statistical significance in fully adjusted model.

[c]Ever told doctor you had trouble sleeping and female sex had interaction effect ($p = 0.066$) of borderline statistical significance in fully adjusted model.

[d]No statistically significant interaction by sex or age group; ×No statistically significant interaction by sex or age group.