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ORIGINAL RESEARCH

# Association of Sleep Duration with Risk of All-Cause and Cause-Specific Mortality Among American Adults: A Population-Based Cohort Study

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**Objective:** To examine potential factors affecting sleep duration and explore its association with the risk of mortality among adults in the United States.

**Methods:** The study population consisted of adults aged 26 to 79 years who participated in the National Health and Nutrition Examination Survey (NHANES) conducted from 2007 to 2016. Sleep duration was classified into three categories: short (<7 hours), optimal (7–8 hours), and long (≥9 hours). The associations between sleep duration and both all-cause mortality and cause-specific mortality (including heart disease, tumors, cerebrovascular disease, and others) were examined in the overall population and subgroups using weighted Cox regression models. Dose-response associations between sleep duration and risk of all-cause mortality were explored using restricted cubic spline (RCS) analyses. Additionally, a multinomial logistic regression analysis was conducted to investigate potential factors that influence sleep duration in adults.

**Results:** The study included a total of 24,141 subjects, with a population-weighted mean age of 48.93 years. Over 30% of the subjects exhibited unhealthy sleep habits. Fully adjusted models revealed that both short sleep duration (HR=1.169, 95% CI 1.027–1.331) and long sleep duration (HR=1.286, 95% CI 1.08–1.531), were associated with an increased risk of all-cause mortality. The RCS curves showed a U-shaped relationship between sleep duration and risk of all-cause mortality. Subgroup analyses showed a significant association between poor sleep patterns and all-cause mortality among adults aged 26–64 years, males, and non-Hispanic whites. Furthermore, multinomial logistic regression identified several predictors associated with short and long sleep durations.

**Conclusion:** Both short and long sleep duration are associated with an increased risk of all-cause mortality, with a U-shaped dose-response relationship. It is imperative to implement appropriate primary prevention strategies aimed at monitoring and providing health education to populations at risk of developing unhealthy sleep patterns.

**Keywords:** sleep duration, mortality, adults, association, NHANES

## Introduction

According to the National Sleep Foundation (NSF), adults are advised to aim for an optimal sleep duration of 7 to 8 hours.[1] However, in contemporary society, characterized by its fast pace and demanding nature, numerous individuals frequently experience sleep deprivation or oversleeping, resulting from factors such as night shifts, unhealthy lifestyles, and prolonged use of electronic screens.[2,3] Reports indicate that close to half of American fail to meet the recommended sleep duration.[4] Children and adults experience beneficial effects on their physical, psychological, and social well-being when they maintain high-quality sleep patterns. Sleep duration has been linked to various biological processes, including inflammation, immunity, insulin and glucose regulation, as well as metabolism.[5,6] Inadequate sleep duration and sleep

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problems are also associated with cognitive decline, depression, suicidal ideation, and other psychological issues.[7] Most studies have identified 7–8 hours as the optimal sleep duration for adults. However, sleep duration exhibits variations and heterogeneity concerning specific disease-related mortality risks.[8] Consequently, additional studies are necessary to investigate the impact of sleep duration on both overall mortality and mortality related to specific diseases. Several factors, among adults, influence sleep duration (particularly on weekdays) and may encompass age, marital status, educational attainment, occupational attributes, and lifestyle.[4,9] The prevalent utilization of social media leads to increased screen time and energy expenditure among adults, impacting their bedtime routines and social interactions.[10] Additionally, gender and racial/ethnic disparities have the potential to contribute to variations in sleep patterns within the population.[11] Given the association between inadequate sleep quality and unfavorable health outcomes, it is imperative to investigate potential factors that impact the duration of poor sleep in adults. Such exploration could facilitate primary prevention and early intervention efforts targeting populations at risk.

This study aimed to evaluate the association between sleep duration and the risk of mortality in adults residing in the United States. Our hypothesis posited that individuals with both inadequate and excessive sleep duration would face a heightened risk of all-cause mortality and mortality related to specific diseases in comparison to those with optimal sleep duration. Additionally, we aimed to investigate potential factors that might impact sleep duration among adults in the United States. The findings of this study possess the potential to yield valuable insights into the connection between sleep duration and outcomes related to mortality, thereby informing future interventions for the prevention and treatment of sleep-related health issues.

# Materials and Methods

## Study Population

Data for this study was obtained from the National Health and Nutrition Examination Survey (NHANES, https://www.cdc.gov/nchs/nhanes/index.htm).[12] NHANES is a research program that conducts sample surveys among the American population to assess the health and nutritional status of adults and children. These surveys cover various factors, including demographics, socioeconomic aspects, dietary patterns, and health-related issues. Participants selected for this study had taken part in the NHANES survey service between 2007 and 2016. Participants under the age of 26 years (n=24,365) were excluded from the analysis. Participants aged 80 years or older (n=1955) were also excluded from the analysis as they were categorized within the 80 years group. After excluding participants with unknown survival status and sleep duration (n=128), a total of 24,141 participants were included in the analysis (Figure 1). This study involving human participants were reviewed and approved by National Center for Health Statistics Research Ethics Review Board.

## Assessment of Sleep Duration

Sleep duration assessment for NHANES participants was conducted through a questionnaire. Trained interviewers asked participants at home, using a computer-assisted personal interview system, about the question, "How much sleep do you usually get at night on weekdays or workdays?". Subsequently, specific data were recorded. Participants who responded to the question were categorized into three groups based on their sleep duration: short sleep duration (<7 hours), optimal sleep duration (7–8 hours), and long sleep duration (≥9 hours).

## Endpoint

Death data for individual participants in NHANES were linked to death certificate records from the National Death Index (NDI, https://www.cdc.gov/nchs/data-linkage/mortality-public.htm). The publicly available NHANES-related mortality rates include deaths attributed to multiple causes. The study focuses on several primary Endpoints, including all-cause mortality, cancer (codes C00-C97), heart disease (codes I00-I09, I11, I13, and I20-I51), cerebrovascular disease (codes I60-I69), and other causes (chronic lower respiratory diseases, accidents, Alzheimer's disease, diabetes mellitus, influenza and pneumonia, nephritis, nephrotic syndrome and other diseases not explained by NHANES) categorized under the ICD-10 codes (International Statistical Classification of Diseases, 10th Revision).

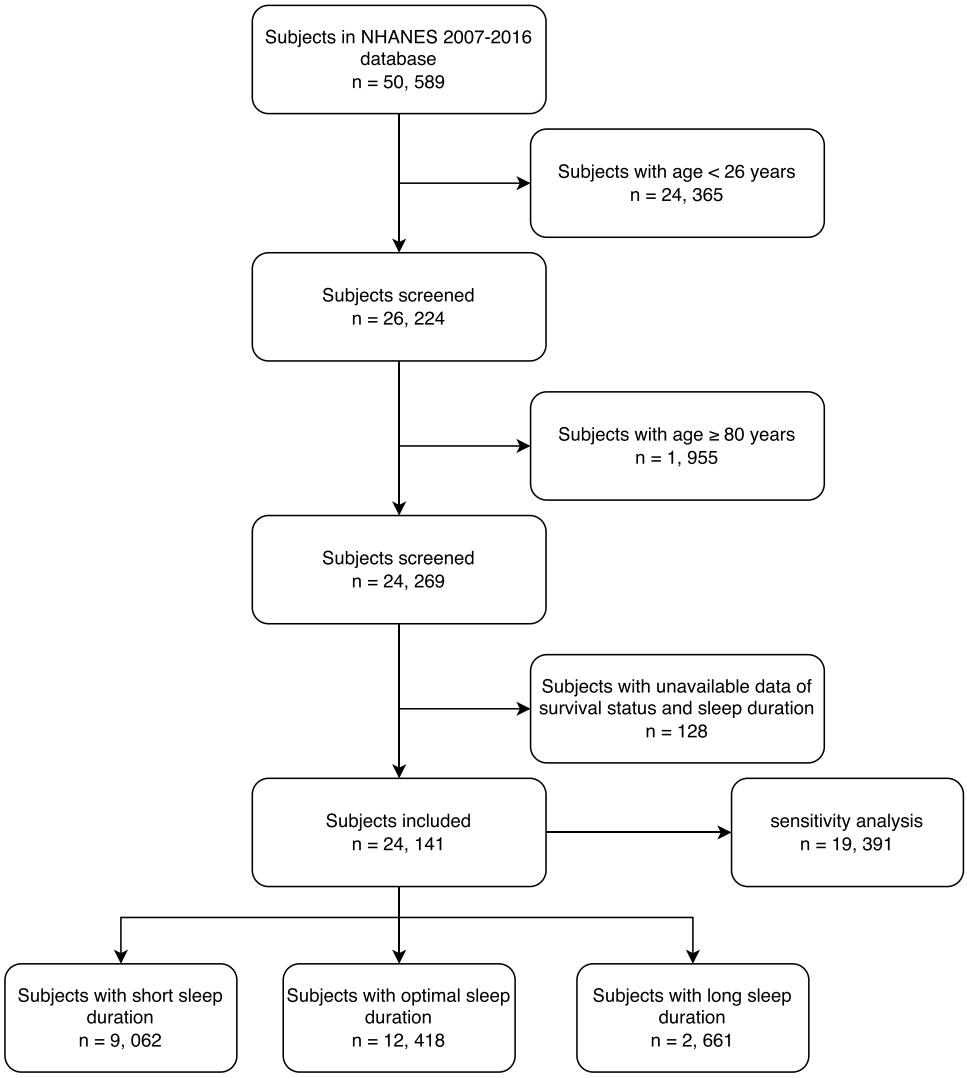


**Figure 1** Flow chart of study participants.

## Covariates

To examine the relationship between sleep duration and mortality more comprehensively, we controlled for several additional variables. Participants were divided into two age groups: adults (26–64 years) and older adults (≥65 years). Race/ethnicity was classified into the following categories: Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and other races. Educational attainment was divided into five categories: less than 9th grade, 9th-11th grade, high school graduate, college or Associate of Arts (AA) degree and college graduate or above. The participant's income level was determined by the ratio of household income to poverty (PIR), with low-income (<1.3), middle-income (1.3–3.5), and high-income (≥3.5) categories.[13] Body mass index (BMI) was employed to evaluate individual's weight status, including normal (≤24.9 kg/m$^2$), overweight (25–29.9 kg/m$^2$), and obese (≥30 kg/m$^2$) categories. Smoking status was classified into three categories: never smoked, formerly smoked, and currently smoked. Alcohol use was categorized into three categories: never drinking, ever drinking, and current drinking. Sedentary time was divided into three categories: none (<6 hours), moderate (6–10 hours), and severe (≥10 hours). Work intensity is categorized according to the number of hours worked per week: high (≥80 hours), moderate (35–80 hours) and low (<35 hours). According to the World Health Organization recommendations for adult physical activity, participants were categorized as follows: vigorous (≥75 min/week of vigorous exercise or ≥150 min/week of moderate exercise), moderately active (<recommended activity level), and inactive.[14] Marital status was categorized as single (widowed/divorced/separated) and non-single (married/living with

partner) based on their living arrangement. The PHQ depression scale was utilized to evaluate the participant's depressive status, classifying them into four groups: none (0–4 points), mildly depressed (5–9 points), moderately depressed (10–14 points), and major depression (≥15 points).[15] Cardiovascular disease (CVD) was defined as a self-reported medical history encompassing congestive heart failure, coronary artery disease, angina pectoris, or heart attack. Diabetes and hypertension were identified based on questionnaire-reported diagnoses and medication usage. Stroke status was also determined through questionnaire responses. Participants were also asked whether or not they are covered by health insurance.

## Statistical Analysis

Representative population studies in NHANES were defined using sampling weights. We utilized the interview and examination weights recommended by NHANES as references. Weighted means ± standard deviation (SD) are reported for continuous variables, whereas categorical variables are presented as counts and weighted percentages. Weighted Cox regression analyses were conducted to examine the association between sleep duration and the risk of all-cause mortality and specific causes of death, while considering sleep duration as a categorical variable (<7 hours, 7–9 hours, ≥9 hours). Model 1 was unadjusted, while model 2 was adjusted for sex, age, and race. Model 3 further adjusted for education, health insurance, body mass index (BMI), smoking status, sedentary behavior, physical activity, marital status, depression, PIR, stroke, diabetes, hypertension, and CVD in addition to the adjustments made in model 2. The results were reported in terms of hazard ratios (HR) and corresponding 95% confidence intervals (CI). Restricted cubic spline (RCS) curves based on cox regression were used to evaluate the relationship between sleep duration, and the risk of all-cause mortality. Additionally, a weighted multinomial logistic regression analysis was conducted to investigate predictors of short and long sleep duration compared to normal sleep duration. The relative risk ratios (RRR) and their corresponding 95% CIs were used for representation. We used STATA for all analyses. Two-tailed P-value < 0.05 was considered statistically significant.

# Results

## General Characteristics of Participants

The analysis included a total of 24,141 subjects who met the criteria. The population had a weighted mean age of 48.93 ± 0.11 years. Among the male subjects (48.4%, n=11,733), the mean age was 48.58 ± 0.16 years, while among the female subjects (51.6%, n=12,408), the mean age was 49.27 ± 0.16 years. The racial/ethnic distribution consisted of 8.39% Mexican, 5.63% other Hispanic, 66.94% non-Hispanic white, 11.27% non-Hispanic black, and 7.77% other races. The overall prevalence rates of short, normal, and long sleep duration were 34.1%, 62.8%, and 3.2%, respectively. The average sleep duration ranged from 6.7 to 7.7 hours among different survey cycle. Stratifying the data by survey period, we observed a gradual increase in average sleep duration among both US adults and older adults, along with an increase in the proportion of individuals with sleep duration exceeding 7 hours (Figure 2). Table 1 presents the population characteristics stratified by sleep duration. When the population was stratified by gender, females showed a higher prevalence of long sleep duration, while males exhibited a greater proportion of short sleep duration. When the population was stratified by age, adults demonstrated a higher prevalence of short sleep duration, while long sleep duration was more commonly observed among older adults. Furthermore, individuals with short sleep duration were more likely to be non-Hispanic black, obese, current smokers, physically inactive, single, and affected by depression and other chronic diseases such as hypertension, diabetes, stroke, and CVD. Supplementary Table 1 displays the baseline characteristics of subjects categorized according to all-cause mortality status. Overall, deceased subjects exhibited a higher likelihood of being elderly, male, non-Hispanic white, obese, smokers, physically inactive, sedentary, and affected by depression.

## Association Between Sleep Duration and Mortality

The patients were followed up for a median of 7.7 years (interquartile range: 5.2–12.3 years) until 2019. The study recorded a total of 2155 deaths. Of these, 460 (21.3%) died from heart disease, 599 (27.8%) from malignancy, 110 (5.1%) from cerebrovascular disease, and 986 (45.8%) from other diseases. Figure 3A and Table 2 demonstrate that subjects with short sleep duration (crude HR=1.3, 95% CI 1.147–1.472) and long sleep duration (crude HR=2.054, 95% CI 1.719–2.454) had

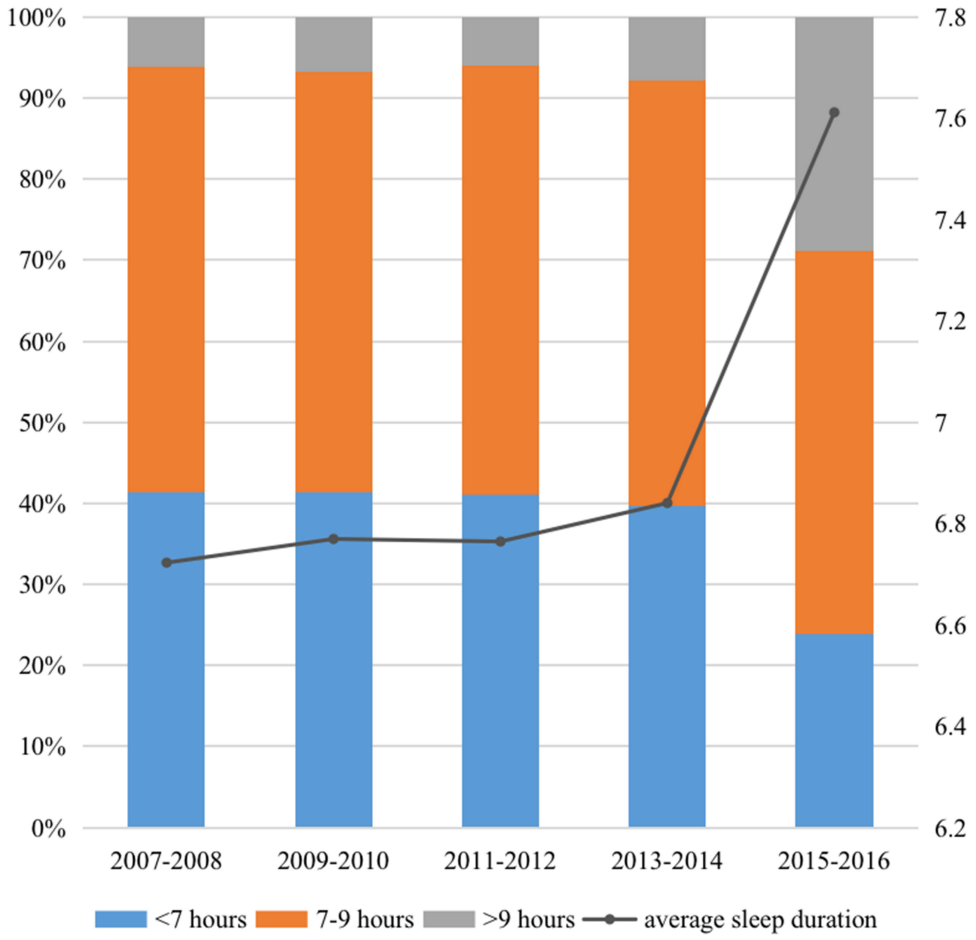


**Figure 2** Prevalence and trends in sleep duration according to survey cycle groupings.

a higher risk of all-cause mortality than those with optimal sleep duration. In the fully adjusted model (model 3), a positive association was found between long sleep duration and the risk of all-cause mortality (HR=1.286, 95% CI 1.08–1.531) and death from malignancy (HR=1.743, 95% CI 1.239–2.451); whereas short sleep duration was also associated with the risk of all-cause mortality (HR=1.169, 95% CI 1.027–1.331). Dose-response associations between sleep duration and risk of all-cause mortality were explored using RCS analyses. The RCS curves showed a U-shaped relationship between sleep duration and risk of all-cause mortality, with lowest risk around 7 hours (Figure 3B). Moreover, we conducted subgroup analysis based on age, sex, and race, revealing significant associations between poor sleep and all-cause mortality in adults aged 26–64, men, and non-Hispanic whites (Supplementary Table 2). Overall, we found that both short and long sleep durations were significantly associated with higher all-cause mortality.

## Sensitivity Analysis

Considering the significant changes in sleep duration among the subject population from 2015–2016, the association between sleep duration and mortality risk could be attributed to alterations in sleep patterns. To test this hypothesis, a sensitivity analysis was conducted, excluding these subjects (n=4, 750). As indicated in Table 2 and Supplementary Table 2, both short (HR=1.161, 95% CI 1.017–1.326) and long (HR=1.316, 95% CI 1.085–1.596) sleep durations were significantly linked to all-cause mortality in adults. However, no correlation was observed between sleep duration and heart disease, malignancy, or cerebrovascular disease. Subgroup analysis revealed that males and individuals aged 26–64 years with short sleep duration and long sleep duration showed increased mortality risk. Additionally, long sleep duration significantly correlated with all-cause mortality among Mexican Americans (HR=1.795, 95% CI 1.097–2.936) and Non-Hispanic Whites (HR=1.337, 95% CI 1.051–1.699). Non-Hispanic Whites also exhibited a significant association with mortality due to sleep deprivation (HR=1.26,

**Table 1** General Characteristics of NHANES Participants from 2007–2016 Stratified by Sleep Duration

| | Sleep Duration | | | P value |
|---|---|---|---|---|
| | <7 Hours | 7–8 Hours | ≥9 Hours | |
| Age | 48.026±0.174 | 49.066±0.155 | 51.129±0.403 | <0.001 |
| Age, years | | | | <0.001 |
| 26–64 | 7453 (87.21%) | 9794 (83.43%) | 1863 (73.46%) | |
| ≥65 | 1609 (12.79%) | 2624 (16.57%) | 798 (26.54%) | |
| Gender | | | | <0.001 |
| Male | 4552 (51.01%) | 6049 (48.26%) | 1132 (40.8%) | |
| Female | 4510 (48.99%) | 6369 (51.74%) | 1529 (59.2%) | |
| Race | | | | <0.001 |
| Mexican American | 1275 (8.24%) | 2072 (8.41%) | 478 (8.8%) | |
| Other Hispanic | 1055 (6.37%) | 1346 (5.16%) | 316 (5.71%) | |
| Non-Hispanic White | 3201 (60.77%) | 5340 (70.51%) | 1077 (68.1%) | |
| Non-Hispanic Black | 2560 (16.38%) | 2152 (8.33%) | 505 (10.25%) | |
| Other Race | 971 (8.24%) | 1508 (7.6%) | 285 (7.14%) | |
| Education | | | | <0.001 |
| Less Than 9th Grade | 939 (5.62%) | 1437 (5.79%) | 401 (7.49%) | |
| 9–11th Grade | 1440 (12.73%) | 1684 (9.63%) | 434 (11.79%) | |
| High school graduate | 2146 (24.4%) | 2590 (19.7%) | 601 (22.29%) | |
| College or AA degree | 2691 (32.48%) | 3281 (28.72%) | 679 (29.13%) | |
| College graduate or above | 1841 (24.72%) | 3414 (36.11%) | 539 (29.14%) | |
| Health insurance | | | | <0.001 |
| Yes | 7024 (80.68%) | 9648 (83.58%) | 2118 (83.21%) | |
| No | 2038 (19.32%) | 2770 (16.42%) | 543 (16.79%) | |
| PIR | | | | <0.001 |
| <1.3 | 2826 (22.05%) | 3279 (15.98%) | 948 (24.33%) | |
| 1.3–3.5 | 3015 (33.01%) | 4028 (30.69%) | 875 (32.45%) | |
| ≥3.5 | 2405 (37.44%) | 3933 (46.3%) | 599 (35.89%) | |
| Work intensity | | | | <0.001 |
| Low | 4671 (44.69%) | 6689 (47.19%) | 1971 (69.03%) | |
| Moderate | 4230 (53.24%) | 5635 (52.01%) | 673 (30.15%) | |
| High | 155 (2.02%) | 86 (0.72%) | 14 (0.76%) | |
| BMI kg/m2 | | | | <0.001 |
| ≤24.9 | 2215 (24.51%) | 3509 (28.86%) | 714 (28.66%) | |
| 25–29.9 | 2836 (32.54%) | 4097 (33.42%) | 776 (29.28%) | |
| ≥30 | 3736 (40.16%) | 4412 (34.82%) | 1075 (39.07%) | |
| Smoke status | | | | <0.001 |
| Never | 4602 (49.37%) | 7034 (56.94%) | 1410 (52.31%) | |
| Former | 2111 (23.91%) | 3099 (26.27%) | 654 (25.37%) | |
| Current | 2343 (26.66%) | 2274 (16.74%) | 595 (22.28%) | |
| Alcohol use | | | | 0.047 |
| Never | 1980 (18.36%) | 2751 (17.95%) | 648 (19.3%) | |
| Former | 1143 (10.75%) | 1426 (9.66%) | 334 (11.28%) | |
| Current | 5664 (68.09%) | 7841 (69.48%) | 1583 (66.43%) | |
| Sedentary behavior, hours | | | | <0.001 |
| <6 | 3865 (39.14%) | 5220 (36.73%) | 988 (33.94%) | |
| 6–9 | 3661 (41.41%) | 5092 (42.47%) | 1194 (45.9%) | |
| ≥10 | 1485 (18.95%) | 2050 (20.46%) | 459 (19.66%) | |
| Physical activity | | | | <0.001 |
| Vigorous | 2561 (31.44%) | 4027 (37.38%) | 686 (31.67%) | |
| Moderately | 1408 (16.61%) | 2109 (18.7%) | 376 (16.84%) | |
| Inactive | 5079 (51.74%) | 6271 (43.84%) | 1598 (51.48%) | |

(*Continued*)

**Table 1** (Continued).

| | Sleep Duration | | | P value |
|---|---|---|---|---|
| | <7 Hours | 7–8 Hours | ≥9 Hours | |
| Marital status | | | | <0.001 |
| Single | 3609 (35.73%) | 4128 (28.63%) | 1044 (34.95%) | |
| Non-single | 5445 (64.23%) | 8284 (71.33%) | 1614 (65%) | |
| Depression | | | | <0.001 |
| None | 5281 (60.33%) | 8740 (72.97%) | 1621 (64.75%) | |
| Mild | 1490 (16.66%) | 1380 (10.78%) | 413 (14.94%) | |
| Moderate | 625 (6.4%) | 426 (3%) | 152 (5.24%) | |
| Severe | 445 (4.28%) | 249 (1.62%) | 123 (4.54%) | |
| Stroke | | | | <0.001 |
| No | 8718 (97.18%) | 12,036 (97.61%) | 2511 (96.1%) | |
| Yes | 335 (2.73%) | 363 (2.27%) | 148 (3.87%) | |
| DM | | | | <0.001 |
| No | 7468 (85.94%) | 10,601 (88.84%) | 2087 (83.68%) | |
| Yes | 1398 (12.05%) | 1605 (9.38%) | 517 (14.26%) | |
| Hypertension | | | | <0.001 |
| No | 5391 (64.08%) | 8170 (68.8%) | 1579 (63.82%) | |
| Yes | 3671 (35.92%) | 4248 (31.2%) | 1082 (36.18%) | |
| CVD | | | | <0.001 |
| No | 8279 (92.98%) | 11,562 (94.29%) | 2393 (92.34%) | |
| Yes | 783 (7.02%) | 851 (5.69%) | 267 (7.64%) | |

**Notes**: Continuous variables were presented as weighted mean ± standard deviation. Categorical variables are expressed as counts (percentages). The percentages and p-values were weighted.
**Abbreviations**: PIR, ratio of family income to poverty; BMI, body mass index; CVD, cardiovascular disease.

95% CI 1.067–1.488). These Results of the sensitivity analysis were compatible with the data shown above, further validating our findings.

## Potential Factors Associated with Sleep Duration

Subsequently, multinomial logistic regression was employed to investigate the predictors of short and long sleep duration (Table 3). The findings suggest that, compared to optimal sleepers, individuals with short sleep duration were more often

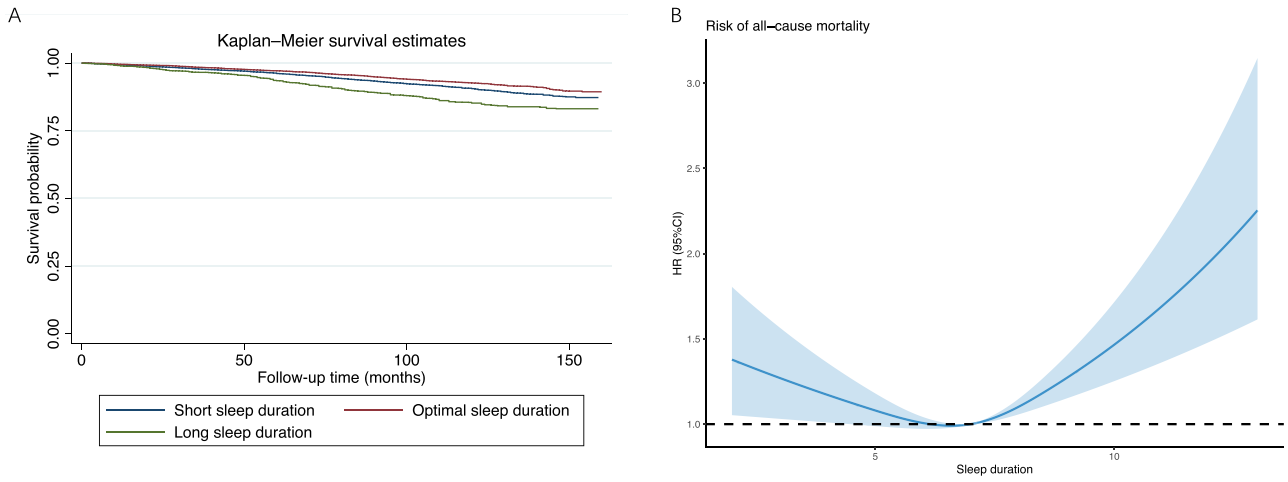


**Figure 3** (**A**) Survival curves for all-cause mortality by weighted Kaplan–Meier method; (**B**) Restricted cubic spline model of the hazard ratios of sleep duration and risk of all-cause mortality. Adjustment for sex, age, race, education, health insurance, BMI, smoking status, alcohol use, work intensity sedentary behavior, physical activity, marital status, depression, PIR, stroke, diabetes, hypertension, and CVD.

**Table 2** Hazard Ratio and 95% Confidence Interval for All-Cause and Cause-Specific Mortality in Relation to Sleep Duration

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| | **HR (95% CI), P** | **HR (95% CI), P** | **HR (95% CI), P** |
| All cause of death | | | |
| <7 hours | 1.3 (1.147–1.472) <0.001 | 1.42 (1.25–1.612) <0.001 | 1.169 (1.027–1.331) 0.018 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 2.054 (1.719–2.454) <0.001 | 1.623 (1.355–1.943) <0.001 | 1.286 (1.08–1.531) 0.005 |
| Heart disease | | | |
| <7 hours | 1.105 (0.864–1.414) 0.427 | 1.063 (0.828–1.365) 0.632 | 0.956 (0.733–1.248) 0.743 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 1.35 (0.989–1.843) 0.059 | 1.408 (1.043–1.901) 0.025 | 1.22 (0.876–1.7) 0.24 |
| Malignant neoplasms | | | |
| <7 hours | 0.858 (0.695–1.06) 0.156 | 0.845 (0.684–1.045) 0.12 | 0.853 (0.679–1.071) 0.17 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 1.736 (1.265–2.382) 0.001 | 1.744 (1.286–2.365) <0.001 | 1.743 (1.239–2.451) 0.001 |
| Cerebrovascular diseases | | | |
| <7 hours | 1.563 (0.924–2.644) 0.096 | 1.558 (0.838–2.897) 0.161 | 0.864 (0.377–1.983) 0.731 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 0.876 (0.458–1.675) 0.689 | 0.895 (0.458–1.748) 0.745 | 0.98 (0.303–3.166) 0.973 |
| Other causes[†] | | | |
| <7 hours | 1.056 (0.893–1.248) 0.527 | 0.994 (0.842–1.173) 0.942 | 1.068 (0.895–1.273) 0.466 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 1.628 (1.284–2.065) <0.001 | 1.638 (1.303–2.059) <0.001 | 1.596 (1.253–2.033) <0.001 |
| **Sensitivity analysis after excluding participants from 2015–2016 (n=19,391)** | | | |
| All cause of death | | | |
| <7 hours | 1.281 (1.129–1.455) <0.001 | 1.405 (1.235–1.599) <0.001 | 1.161 (1.017–1.326) 0.027 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 2.208 (1.815–2.687) <0.001 | 1.689 (1.383–2.062) <0.001 | 1.316 (1.085–1.596) 0.005 |
| Heart disease | | | |
| <7 hours | 1.173 (0.908–1.514) 0.222 | 1.126 (0.869–1.46) 0.368 | 1.047 (0.795–1.378) 0.744 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 1.264 (0.928–1.722) 0.138 | 1.317 (0.975–1.78) 0.073 | 1.146 (0.792–1.658) 0.47 |
| Malignant neoplasms | | | |
| <7 hours | 0.845 (0.68–1.05) 0.129 | 0.833 (0.671–1.034) 0.097 | 0.839 (0.663–1.063) 0.147 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 1.386 (0.983–1.955) 0.063 | 1.416 (1.015–1.975) 0.041 | 1.357 (0.917–2.006) 0.126 |
| Cerebrovascular diseases | | | |
| <7 hours | 1.563 (0.924–2.644) 0.096 | 1.558 (0.838–2.897) 0.161 | 0.864 (0.377–1.983) 0.731 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 0.876 (0.458–1.675) 0.689 | 0.895 (0.458–1.748) 0.745 | 0.98 (0.303–3.166) 0.973 |

(*Continued*)

**Table 2** (Continued).

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| | HR (95% CI), P | HR (95% CI), P | HR (95% CI), P |
| Other causes[†] | | | |
| <7 hours | 1.079 (0.909–1.282) 0.383 | 1.006 (0.848–1.194) 0.945 | 1.094 (0.912–1.312) 0.335 |
| 7–8 hours | Ref. | Ref. | Ref. |
| ≥9 hours | 1.527 (1.178–1.979) 0.001 | 1.54 (1.205–1.968) 0.001 | 1.499 (1.157–1.943) 0.002 |

**Notes**: Model 1 was unadjusted; Model 2 adjusted for sex, age, and race; Model 3 additionally adjusted for education, health insurance, BMI, smoking status, alcohol use, work intensity, sedentary behavior, physical activity, marital status, depression, PIR, stroke, diabetes, hypertension, and CVD on top of Model 2. [†]Other causes include chronic lower respiratory diseases, accidents, Alzheimer's disease, diabetes mellitus, influenza and pneumonia, nephritis, nephrotic syndrome and other diseases not explained by NHANES.

**Table 3** Predictors of Short Sleep Duration and Long Sleep Duration Compared with Optimal Sleep Duration

| | Short Sleep Duration | Long Sleep Duration |
|---|---|---|
| | RRR (95% CI), P | RRR (95% CI), P |
| Age group, years | | |
| ≥65 (vs 26–64) | 0.817 (0.727–0.917) 0.001 | 1.415 (1.21–1.655) <0.001 |
| Gender | | |
| Female (vs male) | 0.877 (0.81–0.95) 0.001 | 1.139 (1.001–1.295) 0.048 |
| Race | | |
| Mexican American | Ref. | Ref. |
| Other Hispanic | 1.236 (1.089–1.403) 0.001 | 0.997 (0.825–1.205) 0.974 |
| Non-Hispanic White | 0.934 (0.835–1.045) 0.236 | 0.876 (0.742–1.033) 0.116 |
| Non-Hispanic Black | 1.836 (1.635–2.063) <0.001 | 0.996 (0.833–1.19) 0.962 |
| Other Race | 1.287 (1.106–1.499) 0.001 | 0.88 (0.705–1.099) 0.259 |
| Education | | |
| Less Than 9th Grade | Ref. | Ref. |
| 9–11th Grade | 1.029 (0.876–1.209) 0.726 | 1.005 (0.803–1.257) 0.967 |
| High school graduate | 1.272 (1.107–1.462) 0.001 | 0.989 (0.799–1.224) 0.919 |
| College or AA degree | 1.385 (1.228–1.561) <0.001 | 1.068 (0.89–1.282) 0.48 |
| College graduate or above | 1.323 (1.187–1.475) <0.001 | 1.007 (0.851–1.193) 0.932 |
| Work intensity | | |
| Low | Ref. | Ref. |
| Moderate | 1.238 (1.136–1.35) <0.001 | 0.489 (0.423–0.565) <0.001 |
| High | 3.183 (2.232–4.54) <0.001 | 0.933 (0.448–1.945) 0.853 |
| Health insurance | 0.924 (0.838–1.019) 0.115 | 0.895 (0.766–1.045) 0.16 |
| PIR | | |
| <1.3 | Ref. | Ref. |
| 1.3–3.5 | 0.908 (0.824–1) 0.051 | 0.844 (0.73–0.976) 0.022 |
| ≥3.5 | 0.862 (0.77–0.966) 0.01 | 0.768 (0.643–0.918) 0.004 |
| BMI kg/m2 | | |
| ≤24.9 | Ref. | Ref. |
| 25–29.9 | 1.13 (1.023–1.248) 0.016 | 0.914 (0.784–1.066) 0.253 |
| ≥30 | 1.189 (1.076–1.314) 0.001 | 1.055 (0.905–1.23) 0.493 |
| Smoke status | | |
| Never | Ref. | Ref. |
| Former | 1.057 (0.959–1.166) 0.264 | 0.958 (0.826–1.112) 0.573 |
| Current | 1.508 (1.361–1.672) <0.001 | 1.325 (1.124–1.563) 0.001 |

(*Continued*)

**Table 3** (Continued).

| | Short Sleep Duration | Long Sleep Duration |
|---|---|---|
| | **RRR (95% CI), P** | **RRR (95% CI), P** |
| Alcohol use | | |
| Never | Ref. | Ref. |
| Former | 1.103 (0.946–1.285) 0.21 | 0.925 (0.737–1.161) 0.5 |
| Current | 0.986 (0.87–1.118) 0.829 | 0.901 (0.748–1.086) 0.273 |
| Sedentary behavior, hours | | |
| <6 | Ref. | Ref. |
| 6–9 | 0.941 (0.865–1.023) 0.154 | 1.193 (1.046–1.36) 0.008 |
| ≥10 | 0.897 (0.802–1.004) 0.058 | 1.226 (1.034–1.454) 0.019 |
| Physical activity | | |
| Inactive | Ref. | Ref. |
| Moderately | 0.904 (0.827–0.99) 0.029 | 0.94 (0.819–1.08) 0.383 |
| Vigorous | 0.893 (0.803–0.993) 0.037 | 0.924 (0.78–1.096) 0.365 |
| Marital status | | |
| Single (vs non-single) | 0.875 (0.806–0.95) 0.001 | 0.903 (0.797–1.023) 0.109 |
| Depression | | |
| None | Ref. | Ref. |
| Mild | 1.728 (1.545–1.932) <0.001 | 1.339 (1.131–1.585) 0.001 |
| Moderate | 2.165 (1.812–2.588) <0.001 | 1.427 (1.096–1.859) 0.008 |
| Severe | 2.604 (2.077–3.266) <0.001 | 2.171 (1.57–3.002) <0.001 |
| Stroke | 0.945 (0.755–1.183) 0.622 | 1.049 (0.786–1.4) 0.746 |
| DM | 1.131 (1.003–1.276) 0.045 | 1.229 (1.026–1.471) 0.025 |
| Hypertension | 1.108 (1.014–1.21) 0.023 | 0.906 (0.793–1.036) 0.148 |
| CVD | 1.087 (0.934–1.265) 0.284 | 0.854 (0.685–1.064) 0.158 |

**Abbreviations**: RRR, relative risk ratio; PIR, ratio of family income to poverty; BMI, body mass index; CVD, cardiovascular disease.

non-white, had higher educational levels, moderate to high work intensity, obesity, were current smokers, and experienced depression, diabetes and hypertension. Additionally, long sleep duration was more frequent among older adults, females, current smokers, those leading a sedentary lifestyle, and individuals with depression and diabetes.

## Discussion

Sleep duration, as a modifiable lifestyle factor, is a global public health concern due to its correlation with health outcomes and quality of life.[16] Our observations indicated that over 30% of US adults, representing the community population, had a sleep duration that did not meet the recommended guidelines. However, there was a trend towards longer average sleep duration. This trend may be overestimated as we did not include individuals under 26 years of age, who may be influenced by additional factors affecting their sleep duration.[17] Sleep duration varies among different genders, age groups, and racial/ethnic backgrounds, we observed a higher prevalence of long sleep duration among female participants compared to males, which is consistent with previous research trends.[18] Additionally, marital status exacerbates demographic differences in sleep duration, particularly among widowed or divorced individuals who may have sole responsibility for caring for other family members, such as children or elderly individuals.[19] An epidemiological study conducted on a healthy population revealed that Asians and Hispanics had significantly shorter sleep durations compared to white participants in the same region.[20] Our findings revealed that non-Hispanic blacks had a higher prevalence of short sleep duration, while whites had a higher prevalence of long sleep duration. Considering the variations in sleep duration prevalence among different genders, age groups, and races, it is crucial to develop population-specific interventions to improve overall health, reduce the risk of death, and achieve optimal sleep duration in diverse populations.

Most studies have identified a "U-shaped" relationship between sleep duration and mortality risk,[21] a finding that aligns with our observations of a significant link between both short and long sleep durations and increased all-cause mortality. Our subgroup analyses revealed statistically significant associations between poor sleep and the risk of death in adults, men, and non-Hispanic whites. Importantly, no significant association was found between sleep duration and all-cause mortality in older subgroups. This discrepancy may stem from the definition of short sleep duration used; studies defining it as ≤5 hours reported a positive correlation with mortality risk,[22] while a definition of ≤6 hours did not show this correlation.[23] Moreover, age appears to be a stronger influencer of the mortality risk associated with short sleep duration, with significant associations observed in older adults aged ≥80 years.[24,25] The prevalence of napping in elderly may mitigate the mortality risks associated with short nocturnal sleep.[26] These results indicates a potential interaction between sleep duration and demographic factors in predicting mortality outcomes. Consequently, sleep duration recommendations should be tailored according to gender, age, and ethnicity.

Although both long and short sleep durations are associated with the risk of death, they may involve different pathways and pathological mechanisms. The possible mechanisms that may link short sleep duration to an increased risk of death are related to sleep deprivation. Sleep deprivation involves various pathological mechanisms, including inflammatory responses, glucose and lipid metabolism disruptions, immune dysfunction, and endothelial dysfunction.[27,28] A meta-analysis found a significant association between sleep disorders and higher levels of C-reactive protein and interleukin 6.[29] Additionally, sleep deprivation or disruption can worsen the development and progression of certain diseases. A study showed that reduced wakefulness after sleep onset was associated with a 60% decrease in mortality among patients with advanced breast cancer.[30]

The relationship between long sleep duration and mortality risk has not been fully elucidated and could be attributed in part to immune and metabolic dysfunction due to circadian rhythm disruption.[31] A significant limitation is the scarcity of studies evaluating the influence of pre-existing health conditions on the sleep duration-mortality nexus. Studies have established an association between prolonged sleep duration and a heightened incidence of cardiovascular ailments, diabetes, coronary heart disease, stroke, and obesity, subsequently influencing mortality risk.[32] This correlation is more distinct in individuals with previously poorer health conditions and may be insignificant among those with superior baseline health.[33] Laboratory studies indicate that healthy individuals given the chance to sleep the physiologically necessary duration will converge to and stabilize at this ideal amount.[34] Consequently, variations in sleep duration may coincide with alterations in specific diseases or social behaviors.[35] Moreover, age is an inescapable confounding variable, with elderly individuals more susceptible to restrictions on their sleep ability due to social factors and circadian rhythms.[36] In addition, long sleep duration is not fully representative of good sleep quality, and drowsiness and fatigue due to poor sleep quality can reduce body resistance and thus lead to increased mortality.[37] However, the causal link between long sleep duration and increased risk of disease and death is not significant, particularly regarding cardiovascular health outcomes.[38]

Sleep duration is affected by various social factors such as employment status, job intensity, and occupational identity.[39] Previous research indicates a significant correlation between unhealthy sleep duration and the prevalence of depression, which was likewise confirmed in our study.[40] Conversely, certain illnesses influence sleep patterns, making it challenging to determine whether changes in sleep duration are a precursor to, a cause of, or a consequence of these diseases. Indeed, the present study cannot conclusively discount the possibility that unassessed comorbidities may extend sleep duration, thereby elevating mortality risk. A thorough comprehension of the causal elements impacting the sleep-mortality relationship is crucial for devising targeted interventions and enhancing quality measures, necessitating further research to clarify the mechanisms linking sleep duration and mortality risk.

Notably, Other modifiable behavioral factors, including diet, physical activity, dietary supplement intake, smoking, and alcohol consumption, may influence the relationship between sleep duration and mortality.[41] Bai et al discovered an interaction effect between vegetable intake and sleep-related mortality, demonstrating that high consumption of vegetables reduced the risk of death associated with poor sleep quality by 9%.[42] Furthermore, sleep deprivation can contribute to sedentary behavior and decreased physical activity levels throughout the day,[43] while daily moderate-intensity physical activity may also reduce some mortality risks associated with poor sleep patterns.[44,45] Therefore, subsequent research should investigate the interplay between sleep duration and these behavioral factors to comprehensively comprehend the intricate associations with mortality outcomes. Furthermore, we have the advantage of identifying potential subgroups with poor sleep patterns can aid in targeting necessary health promotions effectively.

There are several limitations to this study. First, self-reported sleep time records were used instead of objective measures, potentially affecting exposure classification. A study demonstrated that retrospective questionnaires overestimated sleep duration by 20–30 minutes compared to objective measures.[46] Furthermore, the study only assessed weekday sleep duration data, introducing potential bias since long weekend sleep may compensate for shorter weekday sleep.[47] Second, the correlation between mortality and other sleep patterns, such as sleep difficulties and sleep disorders, could not be evaluated due to missing data in certain survey years. Finally, the influence of medication use on result stability was not considered, particularly in the subgroup with prolonged sleep duration.

## Conclusion

Both short and long sleep duration is strongly associated with an increased risk of death, with a U-shaped dose-response relationship. Additional large-scale, prospective studies employing objective measures are necessary to comprehensively investigate this association, particularly focusing on disease-specific studies. Primary prevention strategies and early interventions targeting specific populations with unhealthy sleep patterns are essential, as well as investigating potential causal relationships and underlying mechanisms, with particular attention to unhealthy sleep habits due to comorbidities and other social factors.

## Data Sharing Statement

All data generated or analyzed during this study are included in this published article and its Supplementary Information Files.

## Ethics Approval and Consent to Participate

The studies involving human participants were reviewed and approved by National Center for Health Statistics Research Ethics Review Board. The patients/participants provided their written informed consent to participate in this study.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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