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ORIGINAL RESEARCH

Association Between Sleep Duration and Anxiety in US Adults: A Nationally Representative Cross-Sectional Study

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Background: Previous studies on the relationship between sleep duration and anxiety have yielded inconsistent results. This study aimed to explore this association using data from a large, nationally representative sample of US adults.

Methods: Data from 13,476 participants in the National Health and Nutrition Examination Survey (NHANES) 2007–2012 were analyzed. Weighted robust Poisson regression models were employed to assess the relationship between sleep duration and anxiety, with additional subgroup analyses conducted to explore variations across different demographic groups.

Results: Among participants, 25.8% exhibited symptoms of anxiety. Compared to normal sleep duration (7–9 hours), very short sleep durations (<5 hours) and short sleep durations (5 to <7 hours) were significantly linked to higher anxiety risks, with adjusted incidence rate ratios (IRRs) of 1.40 (95% CI [1.23–1.59]) and 1.17 (95% CI [1.09–1.25]), respectively. Subgroup analyses revealed that shorter sleep durations were more strongly associated with anxiety in males, older adults, racial minorities, and married individuals compared to their counterparts. Notably, long sleep duration (≥9 hours) showed no significant overall association with anxiety (IRR = 1.11 [0.95–1.29]); however, in specific subgroups such as non-married individuals and younger adults, it was linked to an increased risk of anxiety.

Conclusion: Short sleep duration is associated with an increased risk of anxiety, with the strength of this association differing notably across demographic subgroups. Long sleep duration is associated with higher anxiety risk exclusively in specific groups, including non-married individuals and younger adults. Further research is needed to uncover the mechanisms underlying these associations.

Keywords: sleep duration, anxiety, NHANES, mental health, cross-sectional study

Introduction

Anxiety disorders, affecting approximately 34% of the US population, are among the most prevalent mental health issues worldwide.[1] These disorders not only cause significant distress and functional impairment but also frequently co-occur with other mental health conditions and a range of physiological disorders, including neurological, cardiovascular, and gastrointestinal diseases.[2–6] Given their widespread prevalence and profound impact, it is crucial to investigate the underlying mechanisms of anxiety disorders to develop targeted prevention and intervention strategies.

Sleep is fundamental for cognitive and emotional well-being,[7] with disturbances in sleep closely linked to mental health disorders, particularly anxiety.[8,9] Recent research has increasingly focused on the relationship between sleep duration and anxiety. A meta-analysis revealed that individuals with anxiety disorders often experience reduced total sleep time.[10] Similarly, a cross-sectional survey conducted during the COVID-19 pandemic indicated that non-hospitalized individuals who slept seven or more hours per night exhibited a significantly lower anxiety incidence than those who slept less than seven hours.[11] Additionally, a cohort study in Korea found that sleeping between seven to nine hours, as opposed to six hours per day, effectively reduced the likelihood of future anxiety symptoms.[12]

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Furthermore, studies have explored the relationship between short sleep duration and anxiety in specific patient populations, identifying short sleep as a risk factor in patients with stroke,[13] gastrointestinal cancers,[14] and leukemia.[15] However, a two-sample Mendelian randomization study did not support a causal relationship between short sleep duration and anxiety.[16] Nonetheless, this type of research has notable limitations. For instance, it relies on limited population groups, which significantly restricts the generalizability of its findings to more diverse populations,[17] such as the US population examined in the current study. Therefore, the association between short sleep duration and anxiety warrants further investigation across culturally and demographically diverse populations.

Regarding longer sleep duration, some studies suggest that sleep exceeding nine hours does not increase the risk of anxiety.[12] Likewise, the above Mendelian randomization study has not supported a causal relationship between extended sleep duration and anxiety.[16] Nevertheless, other research has found that, compared to seven hours or seven to nine hours of sleep, longer sleep duration (≥10 hours) is significantly associated with higher levels of anxiety.[18–20] Therefore, the relationship between long sleep duration and anxiety also warrants further exploration.

Notably, existing studies have identified the influence of factors such as age, marital status, and socio-economic status on anxiety within the American population. Anxiety levels among Americans increased significantly over the decade from 2008 to 2018, with the most significant increase in younger adults (18–25 years).[21] Compared to peers, individuals who had never been married or had attained higher education levels experienced greater increases in anxiety.[21] White, Hispanic/Latino, and Native American individuals have higher rates of anxiety disorder diagnoses compared to Black individuals.[22] During the COVID-19 pandemic, individuals from lower socio-economic backgrounds reported greater health and economic concerns, along with higher anxiety levels.[23] Furthermore, these demographic factors may also interact with sleep patterns, potentially modifying the relationship between sleep and mental health. For example, adolescents from high-income families experience fewer negative health effects from poor sleep quality.[24] Positive parent-child relationships have been shown to amplify the mental health benefits of good sleep.[25] Physical activity moderates the relationship between sleep and emotional distress, although this effect was significant only among White populations.[26] Additionally, sleep disturbances are common in chronic conditions like diabetes, with research showing that individuals with diabetes who reported short (1–5 h) or long (≥9 h) daily sleep were more likely to report serious psychological distress than individuals who slept 6–8 hours a day.[27] Therefore, when exploring the relationship between sleep duration and anxiety, it is essential to account for the influence of demographic variables, lifestyle factors, and overall health status.

Although prior studies have examined the association between sleep duration and anxiety, findings have been inconsistent. More importantly, few have systematically investigated how this relationship varies across sociodemographic subgroups using nationally representative data from the United States. This study utilizes data from the National Health and Nutrition Examination Survey (NHANES), a robust and nationally representative dataset renowned for its rigorous sampling methodology, which ensures that the findings can be generalized to the broader US population. The study aims to achieve two primary objectives: first, to explore the association between sleep duration and anxiety within a representative population, and second, to examine how this relationship varies across different demographic subgroups. Understanding these relationships is essential for deepening our knowledge of the complex interplay between sleep and anxiety and for guiding targeted public health interventions.

Materials and Methods

Study Population

The NHANES is a comprehensive research program designed to assess the health and nutritional status of adults and children across the United States. The NHANES protocol was approved by the Ethics Review Board of the National Center for Health Statistics, ensuring the ethical treatment of all participants. Each participant provided written informed consent. The dataset used in this study is publicly available and fully anonymized in accordance with NHANES policies. In accordance with Items 1 and 2 of Article 32 of the Measures for Ethical Review of Life Science and Medical Research Involving Human Subjects (issued February 18, 2023, China), research that (1) utilizes legally obtained, publicly available data, or data collected through non-interventional public observation, and (2) involves anonymized information, does not require separate Institutional Review Board (IRB) approval under Chinese national legislation. This cross-

sectional study utilized data from three NHANES cycles conducted between 2007 and 2012. The initial sample included 30,442 participants, but exclusion criteria were applied to refine the study population. Participants were excluded if they were under 20 years of age, had incomplete data on key variables such as anxiety or sleep duration, or lacked information on critical covariates, including age, sex, race, education, marital status, poverty income ratio (PIR), body mass index (BMI), smoking status, alcohol consumption, physical activity, hypertension, diabetes, and depression and sedative-hypnotic drugs. After applying these criteria, the final sample comprised 13,476 subjects (see Figure 1).

Assessment of Anxiety

Anxiety in the NHANES 2007–2012 study was assessed using a self-report question: "During the past 30 days, for about how many days have you felt worried, tense, or anxious?" Detailed information about this anxiety measure is available on the NHANES website (https://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/HSQ_E.htm). Consistent with previous studies,[28–31] anxiety status was classified as "no" (felt anxious for 0–6 days per month) or "yes" (felt anxious for 7–30 days per month).

Assessment of Sleep Duration

Sleep duration in the NHANES 2007–2012 study was assessed through self-reporting. Participants were asked: "How much sleep do you usually get at night on weekdays or workdays?" Detailed information about this sleep measure is available on the NHANES website (https://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/SLQ_E.htm). Based on their responses, sleep duration was classified into four categories: less than 5 hours (very short), 5 to less than 7 hours (short), 7 to less than 9 hours (normal), and 9 hours or more (long).[32]

Assessment of Covariates

Covariate data were meticulously gathered, segmented by diverse demographic factors such as sex (female, male), age categories (20–39, 40–59, ≥60), race/ethnicity (Mexican American, other Hispanic, non-Hispanic White, non-Hispanic Black, other races), educational attainment (below high school, high school graduate, post-high school), marital status (married, separated/divorced/widowed, never married), and poverty income ratio (PIR) classified into ≤130%, 130–350%, and >350%. Participants' smoking and drinking behaviors were categorized into never, former, and current based on their responses to self-administered questionnaires. Individuals who had never smoked 100 cigarettes were labeled as never smokers, those who had smoked at least 100 cigarettes and continued to smoke were designated as current smokers, while former smokers had a history of smoking 100 cigarettes but had since ceased.[33] In terms of alcohol consumption, never drinkers had ingested fewer than 12 alcoholic beverages in their lifetime, former drinkers had consumed at least 12 drinks but abstained in the past year, and current drinkers had both consumed at least 12 drinks and had alcohol intake within the last year.[34] Body mass index (BMI) was stratified into four distinct categories based on physical examination results: underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²), and obese (≥30 kg/m²).[35] Physical activity (PA) was assessed using the Metabolic Equivalent of Task (MET), a standardized measure that evaluates energy expenditure relative to resting metabolic rate and functions as a key marker of exercise intensity.[36] Data were gathered through the Global Physical Activity Questionnaire (GPAQ), with MET values assigned in accordance with NHANES guidelines. Vigorous activities, including both work-related and leisure-time activities, were assigned a MET value of 8.0. Moderate activities, such as work-related tasks, leisure-time activities, and transportation-related tasks like walking or cycling, were assigned a MET value of 4.0. Weekly MET minutes (MET-min/week) were computed by multiplying the MET value for each activity by its weekly frequency and session duration (in minutes), then summing these across all activity types.[37,38] According to the Physical Activity Guidelines for Americans,[39] PA levels were divided into four categories: High-Level Physical Activity (HLPA), defined as >1200 MET-min/week; Moderate-Level Physical Activity (MLPA), covering 600 to 1200 MET-min/week; Low-Level Physical Activity (LLPA), ranging from 1 to 599 MET-min/week; and No Physical Activity (No-PA), corresponding to 0 MET-min/week. Blood pressure readings were taken up to four consecutive times by trained professionals, with the average of a minimum of three measurements determining both systolic blood pressure (SBP) and diastolic blood pressure (DBP). Hypertension was identified if participants met any of the following: a self-reported diagnosis by a healthcare provider, ongoing use of antihypertensive drugs, or an average SBP of 140 mmHg or higher, or an average DBP of 90 mmHg or

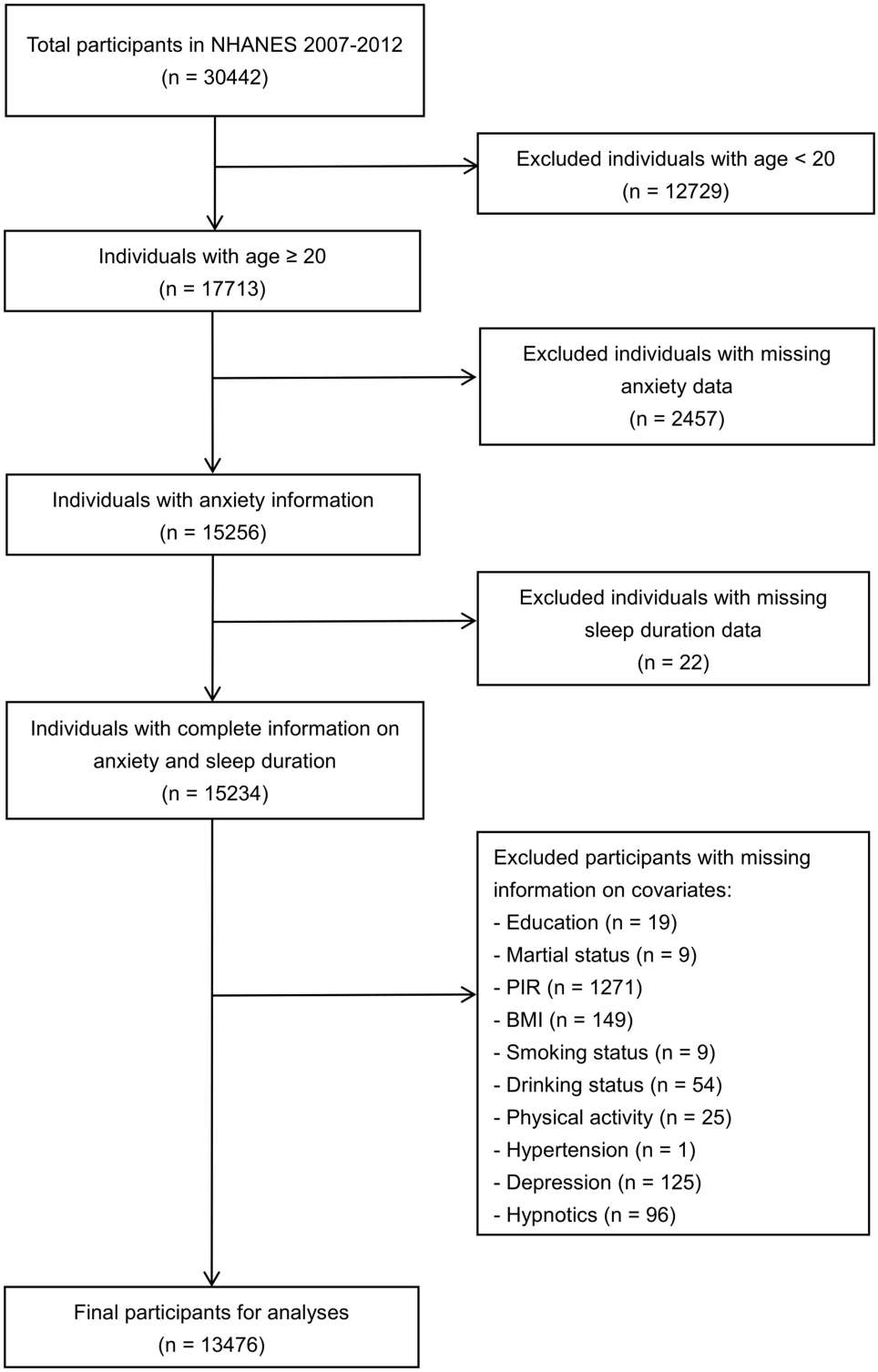

Figure 1 Flowchart of participants inclusion and exclusion.
Abbreviations: BMI, body mass index; PIR, poverty-to-income ratio.

higher during the examination.[28,33] Diabetic status was established based on whether participants had been previously diagnosed, were currently using insulin, or were taking other diabetes-related medications.[40] Depressive symptoms were evaluated using the Patient Health Questionnaire (PHQ-9), with scores of 10 or above indicating the presence of depression.[41] Participants were asked whether they had used any prescription medications in the past month and, if so,

to specify the names of the drugs. This information was used to identify sedative-hypnotic medications, including chlordiazepoxide, clonazepam, oxazepam, flurazepam, estazolam, alprazolam, clorazepate, lorazepam, diazepam, temazepam, triazolam, zolpidem, eszopiclone, and zaleplon.[42]

Statistical Analysis

Unweighted frequencies and weighted percentages were used to describe the categorical variables, ensuring population-representative characteristics. Weighted Chi-squared tests were performed to assess differences between anxiety groups. Weighted Robust Poisson regression was applied to estimate incidence rate ratios (IRRs) and 95% confidence intervals (CIs) for the association between sleep duration and anxiety. Given that over 25% of participants reported anxiety symptoms, logistic regression, which estimates odds ratios, may overstate relative risks, leading to potential misinterpretation. In contrast, robust Poisson regression directly estimates IRRs, offering a more accurate and interpretable measure, particularly when the event rate exceeds 15%, as in this study. By using a sandwich estimator, this method also addresses overdispersion in standard Poisson regression, ensuring stable and reliable estimates. Therefore, robust Poisson regression was preferred over logistic regression or standard Poisson regression due to its suitability for handling high event rates and providing more reliable estimates. Three models were constructed for the analysis: Model 1 with no adjustments; Model 2 adjusted for sex, age, race, education level, marital status, PIR, and BMI; and Model 3 adjusted for sex, age, race, education level, marital status, PIR, BMI, smoking status, drinking status, physical activity, hypertension, diabetes, depression and sedative-hypnotic drugs. Subgroup analyses were performed to evaluate potential effect modification by sex, age, race, education level, marital status, and PIR. All statistical analyses were performed using EmpowerStats (http://www.empowerstats.com) and R software version 4.3.2 (https://www.r-project.org/). A two-sided p-value of <0.05 was considered statistically significant.

Results

The analysis included a total of 13,476 participants, of whom 10,005 (74.2%) did not exhibit anxiety symptoms, while 3471 (25.8%) presented with anxiety symptoms. Table 1 summarizes the general characteristics of the study population, stratified by the presence or absence of anxiety symptoms. Notably, sleep duration differed clearly and significantly between the two groups

Table 1 Sample Characteristics, Overall and Stratified by Anxiety Status

Characteristics	All Participants (n = 13476)	No Anxious Symptoms (n = 10005)	Anxious Symptoms (n = 3471)	P
Sex				**< 0.001**
Female	6779 (51.1)	4709 (48.5)	2070 (58.7)	
Male	6697 (48.9)	5296 (51.5)	1401 (41.3)	
Age (years)				**< 0.001**
20–39	4572 (36.9)	3332 (36.3)	1240 (38.4)	
40–59	4429 (38.6)	3046 (36.7)	1383 (44.2)	
≥ 60	4475 (24.5)	3627 (27.0)	848 (17.4)	
Race				**0.004**
Mexican American	1974 (7.7)	1482 (7.9)	492 (7.0)	
Other Hispanic	1341 (5.1)	939 (4.8)	402 (6.0)	
Non-Hispanic White	6311 (70.5)	4582 (70.1)	1729 (71.7)	
Non-Hispanic Black	2816 (10.6)	2165 (10.8)	651 (10.2)	
Other race	1034 (6.1)	837 (6.4)	197 (5.1)	
Educational attainment				**< 0.001**
Less than high school	3458 (17.1)	2458 (16.0)	1000 (20.5)	
High school	3106 (22.6)	2358 (22.8)	748 (21.7)	
Above high school	6912 (60.3)	5189 (61.2)	1723 (57.8)	

(*Continued*)

Table 1 (Continued).

Characteristics	All Participants (n = 13476)	No Anxious Symptoms (n = 10005)	Anxious Symptoms (n = 3471)	P
Marital status				**< 0.001**
Married	7974 (63.3)	6064 (64.6)	1910 (59.5)	
Separated/Divorced/Widowed	3037 (18.4)	2152 (17.4)	885 (21.2)	
Never married	2465 (18.3)	1789 (18.0)	676 (19.3)	
PIR				**< 0.001**
≤ 130%	4360 (21.5)	2969 (19.4)	1391 (27.6)	
130–350%	4979 (35.2)	3748 (34.9)	1231 (36.1)	
> 350%	4137 (43.3)	3288 (45.7)	849 (36.3)	
BMI (kg/m^2)				**< 0.001**
Underweight	206 (1.5)	133 (1.2)	73 (2.2)	
Normal weight	3704 (29.2)	2792 (29.3)	912 (28.8)	
Overweight	4512 (33.9)	3467 (34.7)	1045 (31.8)	
Obese	5054 (35.4)	3613 (34.8)	1441 (37.2)	
Smoking status				**< 0.001**
Never	7254 (54.5)	5581 (56.6)	1673 (48.6)	
Former	3307 (24.7)	2552 (25.4)	755 (22.4)	
Current	2915 (20.8)	1872 (18.0)	1043 (29.0)	
Drinking status				**< 0.001**
Never	1802 (10.4)	1428 (11.2)	374 (8.0)	
Former	2532 (15.5)	1843 (14.8)	689 (17.4)	
Current	9142 (74.1)	6734 (74.0)	2408 (74.6)	
Physical activity				**< 0.001**
No-PA	3544 (21.5)	2482 (20.0)	1062 (25.8)	
LLPA	1820 (13.3)	1344 (13.3)	476 (13.1)	
MLPA	1739 (13.6)	1331 (13.9)	408 (12.7)	
HLPA	6373 (51.6)	4848 (52.8)	1525 (48.4)	
Hypertension				0.464
No	7823 (63.6)	5822 (63.9)	2001 (63.0)	
Yes	5653 (36.4)	4183 (36.1)	1470 (37.0)	
Diabetes				0.332
No	11762 (90.9)	8773 (91.1)	2989 (90.3)	
Yes	1714 (9.1)	1232 (8.9)	482 (9.7)	
Depression				**< 0.001**
No	12220 (92.1)	9767 (98.2)	2453 (75.0)	
Yes	1256 (7.9)	238 (1.8)	1018 (25.0)	
Hypnotics				**< 0.001**
No	13251 (98.1)	9900 (98.7)	3351 (96.4)	
Yes	225 (1.9)	105 (1.3)	120 (3.6)	
Sleep duration (hours)				**< 0.001**
< 5	799 (4.8)	419 (3.1)	380 (9.6)	
5–7	4550 (31.9)	3238 (30.8)	1312 (35.1)	
7–9	7135 (56.5)	5601 (59.5)	1534 (48.0)	
≥ 9	992 (6.8)	747 (6.6)	245 (7.3)	

Notes: The table presents unweighted sample sizes (n) and weighted percentages (%). P-values in bold indicate statistical significance (P < 0.05).

Abbreviations: BMI, body mass index; PIR, poverty-to-income ratio; No-PA, no physical activity; LLPA, low-level physical activity; MLPA, moderate-level physical activity; HLPA, high-level physical activity.

($P < 0.001$). Additionally, several variables, including age, sex, race, education level, marital status, PIR, smoking status, drinking status, BMI, physical activity, depression, and the use of hypnotics, were all significantly associated with anxiety symptoms.

Table 2 presents the association between sleep duration and anxiety, with IRRs and 95% CIs provided for short sleep durations (<5 hours and 5–7 hours) and long sleep durations (≥9 hours) compared to the mid-range category (7–9 hours). In the unadjusted model (Model 1), participants with less than 5 hours of sleep had a 138% higher risk of anxiety symptoms (IRR = 2.38, 95% CI [2.09, 2.70]), and those sleeping 5–7 hours had a 30% higher risk (IRR = 1.30, 95% CI [1.21, 1.40]). Long sleep durations (≥9 hours) were also associated with a 26% higher risk (IRR = 1.26, 95% CI [1.08, 1.48]). After adjusting for demographic and socioeconomic factors (Model 2), the increased risk of anxiety symptoms remained significant for participants sleeping less than 5 hours (IRR = 2.16, 95% CI [1.91, 2.45]) and 5–7 hours (IRR = 1.28, 95% CI [1.19, 1.37]), while the risk for long sleep durations (≥9 hours) decreased slightly but remained statistically significant (IRR = 1.23, 95% CI [1.05, 1.43]). In the fully adjusted model (Model 3), which included additional lifestyle and health-related factors, the risk associated with less than 5 hours of sleep was reduced but remained significant at 40% (IRR = 1.40, 95% CI [1.23, 1.59]), while the risk for 5–7 hours of sleep persisted at 17% (IRR = 1.17, 95% CI [1.09, 1.25]). The association between long sleep durations (≥9 hours) and anxiety symptoms, however, was no longer statistically significant in this model (IRR = 1.11, 95% CI [0.95, 1.29]).

As shown in Table 3, the association between sleep duration and anxiety varied significantly across demographic subgroups. Among males, very short sleep durations (<5 hours) were strongly associated with a higher anxiety risk (IRR = 1.59 [1.29–1.95]) compared to females (IRR = 1.24 [1.10–1.41]). Short sleep durations (5 to <7 hours) also showed significant associations in both groups, with slightly stronger effects in males (IRR = 1.23 [1.08–1.40]) than in females (IRR = 1.10 [1.01–1.20]). For age, older adults (≥60 years) exhibited greater sensitivity to both very short (IRR = 1.46 [1.15–1.86]) and short sleep durations (IRR = 1.35 [1.15–1.58]) compared to younger adults (<60 years; very short: IRR = 1.38 [1.21–1.56]; short: IRR = 1.12 [1.04–1.21]). Regarding race, racial minorities experienced stronger associations with very short (IRR = 1.39 [1.23–1.57]) and short sleep durations (IRR = 1.20 [1.08–1.34]) compared to Non-Hispanic White individuals (very short: IRR = 1.37 [1.17–1.60]; short: IRR = 1.14 [1.04–1.24]). Marital status further modulated the relationship between short sleep duration and anxiety, with married individuals showing higher anxiety risks associated with very short sleep durations (IRR = 1.47 [1.22–1.77]) than their non-married counterparts (IRR = 1.29 [1.10–1.51]). Notably, long sleep durations (≥9 hours) were generally not significantly associated with anxiety, except in younger adults and non-married individuals, where increased risks were observed.

Table 2 Weighted Robust Poisson Regression Analysis of the Association Between Sleep Duration and Anxiety

	Sleep Duration		Coefficients and Significance				Model Fit Indices			
		B	IRR (95% CI)	Wald χ^2	df	P	Wald χ^2	df	P	AIC
Model 1*	< 5	0.87	2.38 (2.09, 2.70)	179.37	1	**<0.001**	188.00	3	**<0.001**	16,188.02
	5–7	0.26	1.30 (1.21, 1.40)	49.17	1	**<0.001**				
	7–9	Reference	–	–	–	–				
	≥ 9	0.23	1.26 (1.08, 1.48)	8.23	1	**0.006**				
Model 2*	< 5	0.77	2.16 (1.91, 2.45)	150.00	1	**<0.001**	945.89	19	**<0.001**	15,799.01
	5–7	0.25	1.28 (1.19, 1.37)	43.30	1	**<0.001**				
	7–9	Reference	–	–	–	–				
	≥ 9	0.21	1.23 (1.05, 1.43)	6.75	1	**0.014**				
Model 3*	< 5	0.34	1.40 (1.23, 1.59)	27.06	1	**<0.001**	5417.36	30	**<0.001**	15,017.03
	5–7	0.15	1.17 (1.09, 1.25)	17.81	1	**<0.001**				
	7–9	Reference	–	–	–	–				
	≥ 9	0.10	1.11 (0.95, 1.29)	1.81	1	0.194				

Notes: B = unstandardized regression coefficient; IRR (95% CI) = incidence rate ratio with 95% confidence interval, representing the relative risk of anxiety symptoms across sleep duration categories and the precision of the estimate. Wald χ^2 statistics and degrees of freedom (df) are used to assess the statistical significance of individual predictors and the overall model fit. AIC = Akaike Information Criterion, which evaluates model fit while penalizing model complexity; lower AIC values indicate better fit. *Model 1 is the crude model without any adjustments. Model 2 adjusts for age, sex, race, education, marital status, PIR, and BMI. Model 3 further adjusts for smoking status, drinking status, physical activity, hypertension, diabetes, depression, and the use of hypnotics, based on Model 2. P-values in bold indicate statistical significance ($P < 0.05$).

Table 3 Subgroup Analyses for the Effect of Sleep Duration on Anxiety Risk

	< 5		5–7		7–9	≥ 9		P for Interaction
	IRR (95% CI)	P	IRR (95% CI)	P		IRR (95% CI)	P	
Sex								**0.011**
Female	1.24 (1.10, 1.41)	**0.002**	1.10 (1.01, 1.20)	**0.029**	Reference	1.05 (0.88, 1.24)	0.601	
Male	1.59 (1.29, 1.95)	**<0.001**	1.23 (1.08, 1.40)	**0.004**	Reference	1.23 (0.96, 1.57)	0.118	
Age (years)								**<0.001**
< 60	1.38 (1.21, 1.56)	**<0.001**	1.12 (1.04, 1.21)	**0.005**	Reference	1.19 (1.03, 1.39)	**0.026**	
≥ 60	1.46 (1.15, 1.86)	**0.004**	1.35 (1.15, 1.58)	**0.001**	Reference	0.89 (0.67, 1.19)	0.453	
Race								**0.004**
Non-Hispanic White	1.37 (1.17, 1.60)	**0.001**	1.14 (1.04, 1.24)	**0.006**	Reference	1.20 (1.00, 1.44)	0.056	
Other	1.39 (1.23, 1.57)	**<0.001**	1.20 (1.08, 1.34)	**0.002**	Reference	0.84 (0.69, 1.01)	0.071	
Educational attainment								0.456
Above high school	1.47 (1.26, 1.72)	**<0.001**	1.15 (1.05, 1.25)	**0.005**	Reference	1.12 (0.93, 1.35)	0.239	
High School or Less	1.34 (1.15, 1.57)	**<0.001**	1.18 (1.04, 1.34)	**0.017**	Reference	1.08 (0.88, 1.33)	0.476	
Marital status								**0.019**
Married	1.47 (1.22, 1.77)	**<0.001**	1.18 (1.07, 1.30)	**0.002**	Reference	0.98 (0.81, 1.20)	0.855	
Other	1.29 (1.10, 1.51)	**0.004**	1.13 (0.98, 1.30)	0.115	Reference	1.25 (1.03, 1.51)	**0.031**	
PIR								0.133
> 350%	1.50 (1.15, 1.97)	**0.006**	1.25 (1.11, 1.41)	**<0.001**	Reference	1.25 (0.91, 1.71)	0.183	
≤ 350%	1.33 (1.20, 1.49)	**<0.001**	1.10 (1.03, 1.19)	**0.014**	Reference	1.04 (0.91, 1.19)	0.604	

Notes: The model was adjusted for sex, age, race, education level, marital status, PIR, BMI, smoking status, drinking status, physical activity, hypertension, diabetes, depression and sedative-hypnotic drugs. However, the model was not adjusted for the stratification variable itself. IRR (95% CI) = incidence rate ratio with 95% confidence interval, representing the relative risk of anxiety symptoms across sleep duration categories and the precision of the estimate. BMI = body mass index; PIR = poverty-to-income ratio. P-values in bold indicate statistical significance ($P < 0.05$).

Discussion

This study, utilizing data from a nationally representative sample of 13,476 US participants from NHANES, demonstrates a clear association between short sleep duration and increased anxiety risk compared to the recommended 7 to 9 hours of sleep. Both very short sleep duration (<5 hours) and short sleep duration (5 to <7 hours) were independently associated with higher anxiety symptoms, even after adjusting for demographic, lifestyle, and health-related factors. Subgroup analyses revealed that males, older adults, racial minorities, and married individuals exhibited greater sensitivity to the adverse effects of short sleep duration on anxiety. Extended sleep duration (≥9 hours) was typically not associated with anxiety symptoms, but in certain subgroups, such as younger adults and non-married individuals, it was found to elevate the risk of anxiety.

Our findings of a significant association between short sleep duration and anxiety align with previous research.[10–15,43–45] Several mechanisms may underlie this observed relationship. The predominant theory suggests that inadequate sleep impairs brain regions responsible for emotional regulation,[46] a dysfunction commonly observed in individuals with anxiety. Specifically, insufficient sleep increases the amygdala's reactivity to negative stimuli.[47] Research has shown that decreased functional connectivity between the medial prefrontal cortex (mPFC) and the amygdala occurs following total sleep deprivation, five nights of partial sleep restriction (four hours per night), or in individuals who habitually sleep less than 6.5 hours per night.[47–49] This suggests that the heightened reactivity of the amygdala may result from diminished regulatory control by the mPFC. Moreover, short sleep duration has been linked to dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis, leading to increased cortisol secretion,[50] which is strongly associated with anxiety disorders.[51] Additionally, insufficient sleep has been connected to heightened systemic inflammation,[52] a factor that may contribute to the development of anxiety.[53] The combined effects of these physiological changes may help explain the increased risk of anxiety observed in individuals with shorter sleep durations. However, a previous Mendelian randomization study found no causal association between short sleep duration and anxiety,[16] which contrasts with our findings. The observed discrepancy may arise from the fact that Mendelian randomization studies predominantly reflect limited population groups, which greatly limits the applicability of their findings to more diverse groups,[17] such as the US population analyzed in this study. Future research should aim to include more diverse cohorts to more

accurately examine the relationship between sleep duration and anxiety. Additionally, combining genetic approaches with observational studies could provide a more comprehensive understanding of this association.

Our overall analysis did not find an association between long sleep duration and anxiety, which is consistent with some previous studies.[12,16] However, other research has identified a significant link between the two.[18–20] Prather et al found that individuals with longer sleep durations had elevated levels of interleukin-6 and C-reactive protein, suggesting that increased inflammatory cytokines may be a mechanism linking longer sleep with various health conditions.[54] Although there is evidence indicating the impact of inflammation on anxiety,[55] further research is needed to explore this relationship in greater detail.

Our study adds to the existing evidence by highlighting variations in the association between sleep duration and anxiety across demographic subgroups. Notably, our findings show that males may be particularly sensitive to the effects of short sleep on anxiety. While short sleep impairs cognitive and executive functioning in both males and females, males' achievement-oriented tendencies may amplify the psychological impacts of these impairments, potentially increasing their susceptibility to anxiety.[56,57] Furthermore, insufficient sleep, particularly reduced slow-wave sleep, has been linked to lower testosterone levels,[58,59] which are associated with heightened anxiety.[60,61] Together, these findings suggest that males may experience heightened anxiety due to a combination of psychological and physiological vulnerabilities associated with short sleep.

Additionally, our findings indicate that older adults (aged 60 and above) are particularly vulnerable to the negative effects of short sleep on anxiety, likely due to age-related declines in sleep quality. With advancing age, individuals often experience more frequent sleep disruptions and reduced slow-wave sleep, both essential for restorative rest.[62,63] Studies have also linked declines in rapid eye movement sleep to impaired regulation of negative emotions, a more pronounced relationship in older adults.[64,65] In addition to these physiological changes, older individuals may face shifts in social roles, reduced social support, and heightened feelings of loneliness, all of which are strongly associated with anxiety and other negative emotional states.[66,67] These physiological and social factors together may exacerbate the detrimental effects of insufficient sleep, increasing anxiety vulnerability among older adults. By comparison, a significant association between long sleep duration and anxiety is observed primarily in younger individuals. In younger participants, long sleep is associated with elevated levels of inflammatory markers, such as interleukin-6 and C-reactive protein,[54,68] which have been linked to increased anxiety risk.[55] However, in older adults, who often have higher baseline levels of chronic inflammation,[69] this pre-existing state may dampen their physiological sensitivity to additional inflammatory triggers, such as long sleep duration, making the impact less pronounced.

It is worth noting that in the age subgroup analysis, 7 to 9 hours of sleep was uniformly defined as the reference range for all age groups (< 60 years and ≥ 60 years). While this aligns with general sleep guidelines, existing literature presents mixed conclusions about changes in sleep needs with age. Previous research suggest that older adults generally sleep less than younger individuals due to changes in sleep architecture.[70] However, our data showed that older adults reported an average sleep duration of 6.94 hours (SD = 1.49), which was slightly longer than the 6.75 hours (SD = 1.40) observed among younger adults, a statistically significant difference ($t = 7.11$, $df = 13{,}474$, $p < 0.001$). These findings are consistent with some studies suggesting that older adults may require similar or even slightly more sleep than younger individuals,[71,72] challenging the view that sleep needs decline with age. Future studies should focus on developing age-specific sleep reference ranges to better capture older adults' unique sleep characteristics and health outcomes.

Our study also revealed significant racial disparities, with non-majority racial groups in the US showing a higher risk of anxiety linked to short sleep duration. Previous research has suggested that racial and ethnic minorities, as well as socio-economically disadvantaged groups, are more likely to experience sleep patterns associated with adverse health outcomes.[73] This elevated risk may be partly due to chronic stressors, such as cultural attitudes and discrimination, which minority groups are more likely to face. One study found that individuals from minority groups who experienced discrimination during the day were more likely to report sleep disturbances that night.[74] Moreover, these individuals may encounter additional stressors, including low-income challenges, poor housing and community environments, and inadequate social support systems,[75–78] which may further amplify the relationship between short sleep duration and anxiety.

Furthermore, a significant link between short sleep duration and anxiety was evident in both married and unmarried groups, with the connection notably stronger among married individuals. Married individuals, especially

those with children, tend to shoulder greater family responsibilities and caregiving duties,[79] and insufficient sleep can impair their ability to regulate negative emotions, leading to a notable increase in anxiety levels. Additionally, differences in sleep habits or schedules between partners can adversely affect sleep quality.[80,81] Interestingly, unmarried individuals further exhibited the effects of long sleep duration on anxiety. A possible explanation is that unmarried individuals may experience a lack of social support and more irregular lifestyles. Longer sleep duration in this group could reflect inconsistent daily rhythms and a diminished sense of purpose, both of which are strongly associated with anxiety. However, this interpretation requires further exploration in future studies.

This study benefits from the use of NHANES data, providing a large, nationally representative sample and ensuring robust results through adjustments for demographic, lifestyle, and health factors. The analysis of sex, age, race, and marital status subgroups offers new insights into how sleep duration affects anxiety across different demographics. However, this study also has several limitations that should be acknowledged. First, its cross-sectional design precludes the ability to establish causal relationships between sleep duration and anxiety symptoms. Second, both sleep duration and anxiety were assessed using single self-reported items. While these methods are widely used in large-scale epidemiological surveys due to their feasibility and low respondent burden, they are inherently limited in their ability to capture important dimensions such as sleep quality, variability, and disturbances. In addition, self-reported measures are subject to individual misperceptions, particularly in estimating sleep duration. Furthermore, anxiety symptoms often co-occur with other mental health conditions, making it difficult to isolate their independent association with sleep patterns.

Future research should incorporate more comprehensive and objective assessments, such as actigraphy or polysomnography, to improve the accuracy of sleep measurement and validate the current findings. It is also important to consider other potentially influential factors, such as disrupted sleep patterns, elevated stress levels, interference with social and occupational functioning, and underlying or ongoing health conditions, which may mediate or confound the observed associations. In addition, future studies could explore differences in sleep patterns between workdays and weekends, as such variations may offer further insight into the relationship between sleep duration and anxiety, and help inform more targeted intervention strategies.

Conclusions

Findings from this study suggest a potential association between short sleep duration and an increased risk of anxiety symptoms, particularly among males, older adults, racial minorities, and married individuals. In contrast, long sleep duration may be linked to increased anxiety risk only in certain populations, such as younger adults and non-married individuals. These associations should be interpreted with caution due to limitations in the measurement of sleep and anxiety. Further investigation is needed to unravel the mechanisms underlying these associations and inform tailored interventions' design.

Data Sharing Statement

The data utilized in this study are publicly accessible at the following link: https://wwwn.cdc.gov/nchs/nhanes/default.aspx.

Ethics Approval and Consent to Participate

The NHANES protocol was approved by the Ethics Review Board of the National Center for Health Statistics, ensuring the ethical treatment of all participants. Each participant provided written informed consent.

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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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The authors declare there are no competing interests.

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