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The Association Between Sleep Duration and the Likelihood of Depression in US Adult Population

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Abstract. Depression severely impairs individuals' health and daily functioning, positioning it significant public health issue. This study aims to investigate the association between sleep duration and the likelihood of depression in US adults, providing evidence for public health interventions targeting sleep duration and mental health. Utilizing data from the National Health and Nutrition Examination Survey (NHANES) from 2021 to 2023, a total of 1,994 participants were included after adjusting for necessary confounding factors and exclusion of missing values. The measurement of sleep duration relied on self - reported sleep hours during weekdays, while depressive symptoms were evaluated using the Patient Health Questionnaire-9 (PHQ-9). Piecewise regression analysis was conducted with the aim of scrutinizing the relationship between sleep duration and the likelihood of depression. After adjusting for age, sedentary hours and smoking status, among individuals who sleep less than 8 hours, each additional hour of sleep had odds ratio (OR) of 0.657 (95% CI: 0.558, 0.774; $p < 0.001$). On the contrary, among those who sleep 8 hours or more, each additional hour of sleep had OR of 1.607 (95% CI: 1.255, 2.059; $p < 0.001$). A U-shaped relationship emerged between sleep duration and the likelihood of depression: when sleep duration is less than 8 hours, the likelihood of depression decreases with each additional hour of sleep; conversely, when sleep duration is 8 hours or more, the likelihood of depression increases with each additional hour of sleep.

Keywords: depression, sleep duration, piecewise regression

1. Introduction

Depression, clinically referred to as depressive disorders, constitutes a spectrum of mental disorders which significantly impair social functioning, occupational performance, and other critical aspects of daily life [1,2]. Currently, depression has become one of the leading public health issues with approximately 280,000,000 individuals living with depression worldwide in 2023 [3]. The main symptoms of depressive disorders are significant weight loss, insomnia, fatigue, and thoughts of dying or suicide [1]. In severe cases, depression may contribute to self-harm behaviors and fatal

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suicide attempts. Regarding to World Health Organization report, over 700,000 people die by suicide due to depression worldwide every year [3], positioning it a globally critical public health priority. The United States reflects this alarming trend, where data reported by National Institute of Mental Health in 2021 revealed that approximately 21,000,000 adults (8.3% of the adult population) who have experienced at least a significant depressive episode [4].

Sleep, a fundamental physiological process, serves as a dynamic regulator of multisystem homeostasis [5]. Emerging evidence suggests a reciprocal, complicated relationship linking sleep disturbances to depression [6,7]. Substantial studies have demonstrated that sleep problems are common symptoms and critical factors and elevate the likelihood of developing depression [8–10]. Consequently, investigating the interrelationship between sleep duration and depression risk is significant to early prevention, accurate diagnosis, and optimized treatment strategies, and offers a theoretical foundation for intervening in depression via regulating and improving sleep.

Existing research has identified an inverted U-shaped curve linking sleep duration to incidence of depression, which illustrates the risk of depression was found to be negatively correlated with sleep duration, reaching its lowest point at 8 hours, and once sleep duration extended beyond 8 hours, there was a substantial elevation in the risk of depression occurrence [11]. Nevertheless, preceding studies have been limited by inadequate adjustment for some confounding factors or restrictive age ranges [12,13]. To address these gaps, we aimed to conduct a cross-sectional analysis utilizing data from the National Health and Nutrition Examination Survey (NHANES) between 2021 and 2023, examining the association between sleep duration and likelihood of depression in a general adult population in the U.S. We hypothesized the prospect of depression is associated with sleep duration.

2. Methods

2.1. Research population

In this study, we scrutinized data procured from NHANES. The dataset comprised a two-year sample collected from 2021 to 2023 through a multi-year sampling design. This stratified, clustered four-stage sampling means included states, counties, households, and individuals from the U.S. civilian, non-institutionalized population. The initial dataset included 6,329 participants with identification numbers. After the inclusion of necessary covariates and exclusion of cases with missing values, our ultimate analytical sample encompassed 1994 samples (Fig. 1.).

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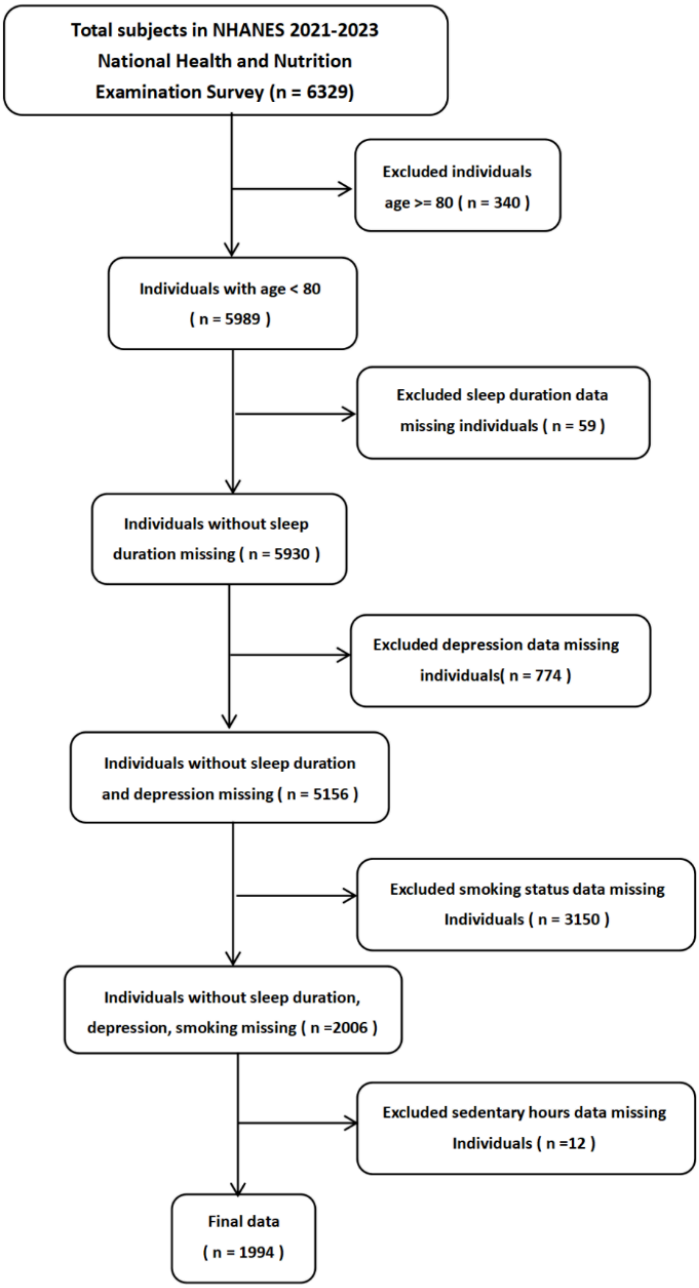

Figure 1. Participants inclusion flowchart

2.2. Measurement

2.2.1. Sleep duration

Sleep Disorders (SLQ) is a module from the NHANES that asked respondents about their sleep and wake times, adapted from the Munich Chrono Type Questionnaire (2003). The variable "Weekdays sleep duration" was a continuous variable ranging from 2 to 14 hours, which was created from one of these questions: "Sleep hours - weekdays or workdays."

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2.2.2. Depression

Mental Health - Depression Screener (DPQ) is an NHANES module which provides a nine-item scale for depression syndromes screening derived from the Patient Health Questionnaire (PHQ-9) to evaluate respondents' depressive syndromes over the preceding two weeks. The PHQ-9 comprises 9 questions. We calculated the overall score (ranging from 0 to 27) of those who completed all nine questions of DPQ. Based on the scoring criteria, we classified respondents' depression categories as follows: no depressive symptoms (with scores between 0 and 4), possible mild depression (with scores between 5 and 9), possible moderate depression (with scores between 10 and 14), possible moderately severe depression (with scores between 15 and 19), and possible severe depression (with scores between 20 and 27). Given that the data is heavily concentrated in the "no depressive symptoms" category while the sample sizes for the other categories are relatively small, the original depression categories were reclassified. Specifically, respondents with a score of 14 or lower were categorized as "unlikely depressed" and those with a score greater than 14 were classified as "likely depressed".

2.3. Other factors

Sex assigned at birth was treated as a binary variable which include male and female. Race was categorized according to how participants responded to the survey questions on race and ethnicity and classified into 7 groups: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Non-Hispanic Asian and Other Race. Education level was categorized into 5 groups: less than 9th grade, 9-11th grade, high school graduate/GED or equivalent, some college or Associate of Arts, college graduate or above, according to the question: "What's the highest school level you've finished up, or the highest degree you've obtained?" Marital status was grouped into 3 main categories: married/living with partner, widowed/divorced/separated and never married. Age was calculated as the years between participants' birth date and interview date. Smoking was grouped by the response to the query: "Do you now smoke cigarettes?" Based on responses to this question, smoking was divided into every day, some days and not at all and we separated them into smoker and non-smoker. Daily sedentary time was a value about how much time a participant usually spends sitting during a standard day and it was converted from minutes to hours to facilitate calculations.

2.4. Statistical analysis

Continuous variables, including weekday sleep duration and daily sedentary hours, were reflected as mean values along with standard deviation (SD). Categorical variables, such as smoking status, possibility of depression and age, were expressed as counts (weighted percentages). Logistic regression analysis was applied to appraisal the odds ratios (OR) with 95% confidence intervals (CI), aiming to appraise the association between the sleep hours and depression level. Hinged on previous research findings, we have noted that the statistical association between sleep hours and the probability of developing depression may not follow a linear pattern. Additionally, we adopted piecewise regression to study the potential nonlinear relationship between sleep hours and depression level. Hinged on the distribution of sleep duration in our data frame, we split sleep duration into two groups: less than 8 hours and 8 hours or more. Further exploration was conducted into the link between sleep hours and depression levels throughout each period. Statistical analyses

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were executed using R software, version 4.5.1, and p-value < 0.05 was established as the criterion for determining statistical significance.

3. Results

This study included 1994 individuals, of whom 1129 (56.6%) were male and 865 (43.4%) were female. The weighted total population number was 58,464,524, after accounting for survey weights. Within this group, the mean age of the participants stood at 55.4 years. Regarding depressive symptoms, an average DPQ score of the sample was 4.64, with 1888 (94.7%) classified as unlikely to be depressed and 106 (5.3%) as likely to be depressed. In terms of smoking habits, 1232 (61.8%) were non - smokers, while 762 (38.2%) were smokers. Additionally, the mean sedentary activity time was 6.2 hours. A summary of the participants' core idiosyncratic can be found in Table 1.

Table 1. Baseline characteristics of participants in the study

Characteristics	Total
N	1994
Sex, n (%)	
Male	1129(56.6%)
Female	865(43.4%)
Education, n (%)	
Less than 11th grade	207(10.4%)
High school	608(30.5%)
Some college	718(36.0%)
College graduate or above	461(23.1%)
Race, n (%)	
Hispanic	239(12.0%)
White	1372(68.8%)
Black	166(8.3%)
Other Race	215(10.8%)
Marital stages, n (%)	
Marriage/living the partner	1194(59.9%)
Divorced/separated/widowed	463(23.2%)
Never married	337(16.9%)
Age(years), Mean (SD)	55.4(15.6)
DPQ score, Mean (SD)	4.64(4.9)
Severity level, n (%)	
Unlikely depress	1888(94.7%)
Likely depress	106(5.3%)
Smoking, n (%)	
Nonsmokers	1232(61.8%)
Smokers	762(38.2%)
Sedentary activity(hours), Mean (SD)	6.2(3.6)

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In this study, we provided qualitative assessment based on sample distribution map (Fig. 2.) and established 8 hours as the turning point for doing regression. To delve deeper into the nonlinear correlation between the length of sleep and the probability of depression, piecewise regression analysis was utilized. The fully adjusted model which is testified to a U-shaped connection between sleep time span and the PHQ-9 score (Fig. 2.). Through further threshold effect analysis (Table 2), we identified 8 hours as the critical threshold in the non-linear pattern between sleep time span and the likelihood of depression among adults. Among individuals sleeping less than 8 hours, each additional hour of sleep was followed with a 34.3% lower likelihood of depression (OR=0.657, 95% CI 0.558- 0.774, p<0.001). However, among individuals sleeping 8 hours or more, each additional hour of sleep was associated with a 60.7% higher likelihood of depression (OR=1.607, 95%CI 1.255, 2.059, p<0.001).

The solid blue line delineates the anticipated value, while the shaded region denotes the 95% CI. These results have been adjusted for factors including age, smoking status, and daily sedentary hours.

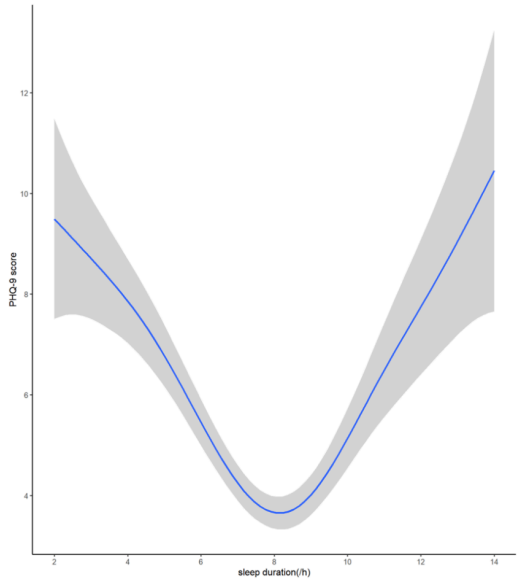

Figure 2. Nonlinear relationship of sleep duration and likelihood of depression

Table 2. Threshold effect analysis of the association of sleep duration on weekdays and the risk of depression

Threshold of sleep hours	OR*	95%CI*	P value
<8	0.657	0.558, 0.774	<0.001
≥8	1.607	1.255, 2.059	<0.001

*For each 1-hour increase in sleep hours. Adjusted for age, smoking status, and sedentary hours per day.

4. Discussion

This study disclosed a U-shaped pattern concerning the relation between sleep duration and probability of depression by using 8 hours as the reference threshold. Individuals with a sleep duration under 8 hours exhibit a higher likelihood of depression, and each additional hour of

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sleeping reduce the likelihood of depression. Conversely, individuals whose sleep duration exceeded 8 hours are linked to a higher likelihood of depression. These outcomes imply that both meager(<8 hours) and exorbitant(>8hours) sleep, taking 8-hour as a reference, may elevate the probability of developing depression in U.S. adults.

Many previous studies have explored the relationship between sleep duration and depression. The study supervised by Liqing et al., which encompassed 34 prospective cohort studies, uncovered a notable link between insomnia and a heightened risk of depression [14]. Régis and his colleagues pointed out that hypersomnia exhibits a multifaceted relationship with depression [15]. Xin-Lin's team, through a dose-response meta-analysis, revealed that not only insufficient but also excessive sleep duration are factors that precipitate a higher incidence of depression [16]. Additionally, previous cross-sectional studies utilizing data from NHANES have also advocated the presence of a U-shaped relationship between the length of sleep and the probability of developing depression [11,17,18]. These results align precisely with our research findings.

Short - term sleep deprivation may have a part to play in the initiation of depressive episodes through several mechanisms. The following are two possible mechanisms. First, insufficient sleep duration significantly diminishes the accessibility of dopamine D2/D3 receptors [19], subsequently leading to attenuated dopamine signal transmission [20], and ultimately resulting in depressive-like behaviors including anhedonia and a lack of motivation [21]. Second, short sleep duration weakens the activity of the right hippocampus in the brain, significantly impairing the human the brain's capacity to hold back unwanted memories [22]. Over the long term, this can precipitate the accumulation of pessimistic emotions and potentially trigger depression. Conversely, excessive sleep duration may also elevate the peril of depression through several pathways. One possible explanation, sleeping for long periods of time may lead to a decline in cognitive ability, which can slash individuals' abilities to cope with stress, forming a vicious cycle of "sleep disorder - cognitive decline - worsening depression" [23]. Additionally, long sleep duration may weaken the abilities of emotional regulation by inhibiting prefrontal cortex activity [24], potentially leading to manifestations such as irritability and excessive self-blame [25], thereby increasing the susceptibility to depression. Finally, long time sleeper may experience increased loneliness owing to reduced social activity, which in turn amplifies boredom and indirectly increases the tendency toward depression [26].The comorbidity of sleep disorders and major depressive disorder implies a potential bidirectional interaction between them, indicating that sleep problems can potentially exacerbate depressive symptoms, and conversely, depressive states can also impact sleep [27–29].

Several significant strengths are inherent in our study. First, our study population included adults aged from 18 to 79, which covered a relatively wide range of ages in adults' population. Thus, the results of our study can have a broad generalizability among people of different ages. Second, we took both demographic and lifestyle factors (age , smoking status [30], and sedentary hours per day [31]) as our consideration to adjust our models. Moreover, we employed piecewise regression to flexibly capture the nonlinear linkage between the number of sleep hours and likelihood of depression. In this way, we captured complex U-shaped relationship within the data. However, we must point out that our study is accompanied by certain limitations. In the first place, we are incapable to obtain the provenance from the results due to the cross-sectional nature of the study. Long - term follow - up studies are imperative to infer causality between sleep hours and the likelihood of depression. Moreover, because our dependent and independent variables chosen from NHANES are both self-reported, potential misclassification biases are existing, such as subjective interpretation differences, social desirability bias, and recall bias. Furthermore, because of the relatively large number of missing data, we are incapable of adjusting all confounding factors, such

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as health condition [32], living condition [33], etc. Therefore, residual confounding factors are inevitable.

5. Conclusion

In conclusion, this study revealed that there is a U-shaped link between how long people sleep and their chance of having depression. When sleep hours less than 8, the likelihood of depressive disorder decreases as the sleep length increases. Meanwhile, when sleep duration exceeds or equal to 8, the likelihood of depressive disorder increases as the sleep length increases. As indicated by this finding, sleep duration may serve as a practical indicator for mental health assessment.

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