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Independent and Nonlinear Associations of Sedentary Time and Weekday Sleep Duration with Depressive Symptoms among U.S. Adults: NHANES 2021-2023

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Abstract. This study uses the data of National Health and Nutrition Examination Survey to investigate how sedentary time and weekday sleep duration are related to depressive symptoms among U.S. adults and its potential effect modification on the sedentary time–depressive symptoms association were also assessed. A total of 4,449 participants aged 20 years and above who took part in NHANES 2021–2023 were included. A PHQ-9 score of ≥10 was used to identify more pronounced depressive symptoms. Survey-weighted regression models were used for the analyses. For every one weighted SD increase in sedentary time, the odds of more pronounced depressive symptoms were 15.0% higher (OR = 1.150, 95% CI: 1.028–1.286). Compared with 7–9 hours of weekday sleep, short sleep was associated with higher odds of depressive symptoms (OR=1.772, 95% CI: 1.395-2.250). A U-shaped association was observed between sleep duration and depressive symptoms, with a model-estimated nadir of approximately 8.4 hours. No significant effect modification by weekday sleep duration was observed. Longer sedentary time and shorter weekday sleep duration were associated with more pronounced depressive symptoms. It still needs more longitudinal studies to establish the temporal sequence of these relationships.

Keywords: Sedentary time, Weekday sleep duration, Depressive symptoms, Nonlinear association, NHANES

1. Introduction

Depressive symptoms are an important public health concern that may reduce quality of life and impair daily functioning.Sedentary behavior is increasingly prevalent in contemporary lifestyles and is linked to multiple adverse health outcomes. It generally refers to low-energy-expenditure behavior performed while awake in a sitting or reclining posture. Prior research has linked longer sedentary time to greater depressive symptom severity [1, 2]. Weekday sleep duration is also relevant to depressive symptoms, and different durations may correspond to different symptom levels.

This study investigated whether sedentary time and weekday sleep duration were independently related to depressive symptoms and whether the relationship between sleep duration and depressive symptoms was nonlinear [3].

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The study used NHANES 2021–2023 data for a cross-sectional analysis with survey-weighted regression models.

Previous studies have often examined sleep duration and sedentary time separately. By considering both factors simultaneously and with a focus on whether weekday sleep duration altered how sedentary time was related to depressive symptoms, the present analysis provides substantial complementary evidence to the existing literature.

2. Methods

2.1. Participants

NHANES 2021–2023, administered by the U.S. National Center for Health Statistics, served as the data source for this analysis [4]. The analysis was restricted to participants who were at least 20 years old. Participants with missing data on sedentary time, weekday sleep duration, PHQ-9 items, covariates, or complex survey design variables were excluded. The final analytic sample comprised 4,449 participants.

2.2. Measures

2.2.1. Outcome ascertainment

Depressive symptoms were evaluated with the nine-item Patient Health Questionnaire-9 (PHQ-9), with scores ranging from 0 to 27 [5]. Higher scores reflected greater symptom severity. A score of ≥10 defined more pronounced depressive symptoms in the primary analysis, while the total score was analyzed continuously in the secondary analysis.

2.2.2. Exposure measurement

Sedentary time and weekday sleep duration were treated as exposure variables. Sedentary time was assessed based on participants' self-reported usual daily time spent sitting or reclining and was measured in minutes per day.Weekday sleep duration was divided into three categories: short sleep (<7 hours), 7-9 hours, and long sleep (>9 hours). Values of less than 3 hours or 14 hours or more were coded as missing and excluded from the analysis. The 7-9-hour group was used as the reference category in the regression analyses. Weekday sleep duration was additionally modeled as a continuous measure to assess its nonlinear association with depressive symptoms.

2.2.3. Covariate assessment

The choice of covariates was informed by previous research on sleep, sedentary behavior, and depressive symptoms, considering their potential confounding effects. Demographic and socioeconomic covariates included age, sex, race/ethnicity, education, family income-to-poverty ratio, and BMI. Age, family income-to-poverty ratio, and BMI were modeled as continuous variables, whereas the remaining covariates were treated as categorical variables.

2.3. Statistical analysis

The complex NHANES survey structure was incorporated throughout the analyses through MEC examination weights, strata, and primary sampling units. Continuous variables were summarized by

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survey-weighted means and corresponding standard errors Design-adjusted tests were applied to compare differences between groups.

Daily sedentary time and continuous weekday sleep duration were Z-standardized using survey-weighted means and standard deviations. Associations with PHQ-9 scores ≥10 were evaluated using survey-weighted multivariable logistic regression. Sedentary time was modeled continuously, while categorical sleep-duration analyses used the 7–9-hour group as the comparison category. Covariate adjustment included age, sex, race/ethnicity, educational attainment, family income-to-poverty ratio, and BMI. Model effects were expressed using odds ratios accompanied by 95% confidence intervals.

Nonlinearity was assessed by including linear and quadratic terms for standardized weekday sleep duration in the adjusted survey-weighted logistic model. Their joint significance was evaluated using a design-adjusted Wald test, and the curve nadir was calculated from the model coefficients. Effect modification was examined by separately adding interactions between standardized sedentary time and sleep-duration categories or continuous sleep duration. All interaction models retained the corresponding main effects, and Wald tests were used to assess the interaction terms.

In this secondary analysis, the full PHQ-9 score was retained on a continuous scale. Multivariable linear regression models incorporating the complex survey design were used to estimate how depressive symptom scores varied with daily sedentary time and weekday sleep duration.

In this sensitivity analysis, the sample was restricted to participants with weekday sleep durations of 4-12 hours. The multivariable logistic regression analysis containing the linear and quadratic terms of sleep duration was then repeated to determine whether the nonlinear pattern remained consistent.

Statistical significance was defined as $P < 0.05$ using two-sided testing. All analyses were performed using R software, using the survey package to account for the complex sampling design.

3. Result

3.1. Study population characteristics

The final analytic sample comprised 4,449 participants, of whom 3,905 had PHQ-9 scores below 10 and 544 had scores of 10 or higher. Participants experiencing depressive symptoms were younger and had shorter sleep duration, lower family income-to-poverty ratios and higher BMI values. This group also included a greater proportion of women. The distributions of sleep-duration categories and educational attainment differed significantly across the two groups, whereas race/ethnicity and unadjusted daily sedentary time did not differ significantly (Table 1).

3.2. Associations of sedentary time and weekday sleep duration with depressive symptoms

For each weighted-SD increase in sedentary time, the odds of depressive symptoms were 15.0% higher. Relative to 7–9 hours of sleep, short sleep corresponded to significantly greater odds of depressive symptoms. A U-shaped pattern emerged when depressive symptoms were modeled across sleep duration, with a model-estimated nadir of approximately 8.4 hours (Table 2).

3.3. Effect modification by weekday sleep duration

Both interaction tests were non-significant, providing no support for effect modification by weekday sleep duration.

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3.4. Secondary and sensitivity analyses

In secondary analyses, each weighted-SD increase in sedentary time was associated with a 0.39-point higher PHQ-9 score (β=0.391, 95% CI: 0.270–0.513; P<.001). Short and long sleep were each associated with approximately 1.30-point-higher scores than 7-9 hours of sleep. Restricting sleep duration to 4-12 hours produced similar results, including a significant quadratic association and a model-estimated nadir of 8.34 hours.

Table 1. Weighted characteristics of the study population according to depressive symptom status

Characteristic	PHQ-9 <10(n=3,905)	PHQ-9 ≥10(n=544)	P value
Age, years	49.52 (0.58)	43.88 (1.08)	<.001
Sedentary time, min/day	371.31 (7.06)	386.43 (15.22)	.227
Weekday sleep duration, hours	7.69 (0.03)	7.45 (0.08)	.006
Family income-to-poverty ratio	3.23 (0.10)	2.36 (0.12)	<.001
BMI, kg/m²	29.56 (0.30)	31.12 (0.33)	.005
Sex			.002
Female	49.7%	60.9%	
Race/ethnicity			.406
NH White	64.8%	61.4%	
Hispanic	14.4%	16.2%	
NH Black	9.3%	11.6%	
Other racial/ethnic groups	11.5%	10.8%	
Education level			.005
High school	68.7%	59.5%	
Below high school	23.7%	30.6%	
Less than high school	7.6%	10.0%	
Weekday sleep-duration category			<.001
7–9 h	72.2%	58.6%	
Short sleep (<7 h)	19.3%	29.0%	
Long sleep (>9 h)	8.5%	12.3%	

Weighted means and standard errors were used for continuous measures, while categorical data were summarized by weighted proportions. The column headings indicate the unweighted sample sizes. P values were derived from survey-adjusted tests incorporating MEC examination weights, strata, and primary sampling units. BMI, body mass index; PHQ-9, Patient Health Questionnaire-9.

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Table 2. Associations of sedentary time and weekday sleep duration with depressive symptoms

Analysis	Exposure or term	Effect estimate (95% CI)	P value
	Panel A. Joint adjusted logistic model		
	Sedentary time, per weighted SD	OR 1.150 (1.028–1.286)	.018
	Short weekday sleep (<7 h)	OR 1.772 (1.395–2.250)	<.001
	Long weekday sleep (>9 h)	OR 1.356 (0.868–2.117)	.166
	Panel B. Nonlinear weekday sleep model		
	Sedentary time, per weighted SD	OR 1.144 (1.021–1.283)	.024
	Weekday sleep duration, linear term	β −0.147 (−0.249 to −0.046)	.007
	Weekday sleep duration, quadratic term	β 0.140 (0.089–0.190)	<.001
	Joint Wald test for sleep terms	F=37.63 (2, 15 df)	<.001
	Model-estimated nadir	8.40 hours	—
	Panel C. Effect-modification analyses		
	Sedentary time × sleep-duration categories	Wald F=0.557	.584
	Sedentary time × continuous sleep duration	OR 1.055 (0.985–1.131)	.118
	Panel D. Secondary analysis: continuous PHQ-9 score		
	Sedentary time, per weighted SD	β 0.391 (0.270–0.513)	<.001
	Short weekday sleep (<7 h)	β 1.297 (0.836–1.757)	<.001
	Long weekday sleep (>9 h)	β 1.296 (0.674–1.918)	<.001

All models accounted for the NHANES complex survey design and were adjusted for age, sex, race/ethnicity, educational attainment, family income-to-poverty ratio, and BMI.

In Panel A and Panel D, the 7-9-hour sleep group was the reference category. Sedentary time and continuous sleep duration were standardized using survey-weighted means and standard deviations.

In Panel B, the linear and quadratic sleep terms should be interpreted jointly. The joint Wald test evaluated their overall association, whereas the quadratic term assessed nonlinearity.

The continuous interaction estimate in Panel C is presented as an exponentiated coefficient (OR). CI, confidence interval; OR, odds ratio; PHQ-9, Patient Health Questionnaire-9; SD, standard deviation.

4. Discussion

4.1. Sedentary time and depressive symptoms

Our findings echoed earlier research, showing greater depressive symptom severity among participants with longer sedentary time [1]. This association may be partly related to reduced physical activity [2, 6]. However, the cross-sectional nature of the data prevented us from establishing the temporal sequence, and reverse causation remains possible.

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4.2. Depressive symptoms across weekday sleep duration

The present analysis linked short sleep to greater depressive symptom severity and showed that tdepressive symptom patterns across different sleep durations followed a U-shaped pattern, in agreement with earlier research. Shorter sleep duration may affect emotional regulation and may also contribute to fatigue or circadian disruption. In the categorical analysis, the odds ratio for long sleep was greater than 1 but was not supported statistically. Meanwhile, the nonlinear analysis identified a significant U-shaped association, and long sleep was associated with higher PHQ-9 scores when PHQ-9 was analyzed as a continuous outcome [3].

4.3. Effect modification by weekday sleep duration

This study found no evidence that weekday sleep duration modified how sedentary time related to depressive symptoms. However, this should not be interpreted as evidence that effect modification is completely absent. The lack of statistical significance for the interaction may be related to factors such aslimited statistical power and the small long-sleep subgroup in the long-sleep group, and measurement error arising from self-reported data; therefore, these findings should be confirmed in future studies.

5. Conclusion

Using NHANES 2021–2023 data, we evaluated how sedentary time and weekday sleep duration were related to depressive symptoms in U.S. adults. After standardizing sedentary time and controlling for weekday sleep duration and the remaining covariates, longer sedentary time remained associated with more pronounced depressive symptoms. Participants with shorter weekday sleep showed greater depressive symptom severity. Moreover, depressive symptoms followed a U-shaped pattern across weekday sleep duration, with a model-estimated nadir of approximately 8.4 hours. The interaction analyses found no evidence that weekday sleep duration modified how sedentary time related to depressive symptoms. Taken together, sedentary behavior and unsuitable sleep duration may represent separate behavioral factors related to depressive symptoms. Therefore, mental health research and public health interventions may benefit from simultaneously addressing excessive sedentary time and from maintaining an appropriate sleep duration.

These findings should be interpreted in light of several limitations. Because the data were cross-sectional, the temporal sequence could not be established, and reverse causation remains possible. Sedentary time and weekday sleep duration relied on participant reports and may therefore contain measurement error. In addition, the PHQ-9 serves as a tool for screening depressive symptoms rather than confirming a clinical diagnosis. Future longitudinal studies with larger samples, objective measures of sedentary behavior and sleep, and more comprehensive sleep indicators are needed to verify these findings and to clarify the temporal relationships involved.

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