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Serum Vitamin D, Sleep Duration, and Depressive Symptoms among U.S. Adults: A Cross-sectional Analysis of NHANES

Yuheng Li

New York University Steinhardt School of Culture, Education, and Human Development, New York University, New York, USA
yl11063@nyu.edu

Abstract. Vitamin D has been linked to mental health, but the relationship between serum vitamin D and depressive symptoms remains inconsistent. Sleep duration is also strongly related to depression and may provide important context for understanding this association. Focusing on sleep duration as a potential modifying factor, this research explored whether serum 25-hydroxyvitamin D is associated with depressive symptoms among American adults. Publicly accessible NHANES data served as the source for the present analysis.Depressive symptoms were assessed using the PHQ-9, and serum vitamin D was measured as serum 25-hydroxyvitamin D concentration. Sleep duration was included as both a covariate and a possible effect modifier. Exploratory data analysis was first conducted to describe sample characteristics and depressive symptom prevalence across vitamin D groups. Logistic regression models were then fitted to derive odds ratios, both unadjusted and adjusted for covariates. The results showed that vitamin D deficiency appeared to be associated with a higher prevalence of depressive symptoms, but the association was not statistically significant after adjusting for covariates.Sleep duration showed a stronger pattern in the model. Overall, these findings suggest that the vitamin D–depression relationship should not be considered in isolation; sleep duration offers valuable context for future nutritional epidemiology research.

Keywords: vitamin D, depressive symptoms, sleep duration, NHANES, nutritional epidemiology

1. Introduction

Vitamin D is an important nutrient and biomarker that is commonly discussed in relation to bone health, immune function, and general health status. Recent studies have also explored whether vitamin D is associated with mental health outcomes, particularly depressive symptoms. Depression is a major public health problem because it can affect daily functioning, quality of life, chronic disease management, and health behavior. Since vitamin D status can be measured objectively through serum 25-hydroxyvitamin D concentration, it provides a useful nutritional biomarker for population-based research. Inconsistent results have been reported in prior research on the association between low serum vitamin D and depressive symptoms. The literature presents divergent results, with certain studies indicating that low vitamin D may predispose to depression,

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while others find that the association becomes weak or loses significance when demographic and lifestyle factors are included in the model [1]. One possible reason for these inconsistent findings is that vitamin D does not act in isolation. Depressive symptoms are influenced by many factors, including sleep, physical activity, body weight, chronic disease, socioeconomic status, and other health behaviors. Sleep duration is especially important in this context. Sleep is closely related to mental health, and both short and long sleep have been associated with worse health outcomes in prior research [2]. Sleep duration may also be linked to vitamin D status through outdoor activity, physical activity, obesity, and overall health. Therefore, considering sleep duration may help provide a more complete understanding of the vitamin D–depression relationship. The objective of this paper was to test for an association between serum vitamin D status and depressive symptoms in U.S. adults. It also evaluates whether sleep duration modifies this association. The analysis uses NHANES data, applying exploratory data analysis and logistic regression models. The main contribution of this study is not simply to repeat the question of whether vitamin D is related to depression, but to examine vitamin D, sleep duration, and depressive symptoms in the same statistical framework.

2. Methods

2.1. Data source and study population

The National Health and Nutrition Examination Survey (NHANES)—a nationally representative dataset overseen by the CDC and the National Center for Health Statistics—served as the source of data for the current analysis. NHANES provides questionnaire data, physical examination measures, and laboratory biomarkers from a nationally representative sample of the U.S. population [3]. This makes it especially useful for nutritional epidemiology research because it includes both self-reported health information and laboratory-based biomarkers.

The analysis used publicly available NHANES data modules that included demographic variables, serum vitamin D laboratory data, depressive symptom questionnaire data, sleep questionnaire data, and body measurements. Participants were linked across data files using the unique respondent identifier SEQN. The study population included adults with available data on serum vitamin D, PHQ-9 depressive symptoms, sleep duration, BMI, and selected covariates. After merging the data and excluding participants with missing values for the main variables, the final analytic sample consisted of 4,744 adults.

2.2. Outcome variable: depressive symptoms

The main outcome was depressive symptoms. NHANES employed the nine-item PHQ-9 depression screener for the assessment of depressive symptoms [4]. Participants were asked by the PHQ-9 to report the frequency of nine symptoms over the preceding two weeks, including diminished interest or pleasure, depressed mood, sleep disturbances, fatigue, appetite changes, concentration difficulties, and self-harm ideation. The PHQ-9 is a reliable and validated measure of depression severity [5].

A composite PHQ-9 score was generated in the present analysis by adding together all nine item scores. Participants with a score of 10 or higher were categorized as having depressive symptoms; those with lower scores were categorized as not having depressive symptoms. This created a binary outcome variable suitable for logistic regression.

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2.3. Main exposure: serum vitamin D

The main exposure was serum vitamin D status, measured as serum 25-hydroxyvitamin D. In NHANES, serum vitamin D is measured from laboratory samples — an advantage because it does not rely solely on dietary recall or self-report. In NHANES, the vitamin D data comprise total 25-hydroxyvitamin D—that is, the aggregate of 25-hydroxyvitamin D2 and 25-hydroxyvitamin D3 [6].

For descriptive and regression analyses, serum vitamin D was categorized into three groups: deficient, insufficient, and sufficient. A serum 25-hydroxyvitamin D value under 30 nmol/L was established as the criterion for vitamin D deficiency. Insufficiency was defined as 30 to below 50 nmol/L, and sufficiency was defined as 50 nmol/L or higher. The sufficient group was used as the reference group in logistic regression models.

2.4. Sleep duration and covariates

Sleep duration was included as both a covariate and a possible effect modifier. NHANES provides sleep questionnaire variables, such as usual sleep duration in hours [7]. Three sleep duration groups were defined: short sleep, normal sleep, and long sleep. Short sleep was considered as less than 7 hours per night. Normal sleep referred to 7 to 9 hours per night. Long sleep was designated as more than 9 hours per night.

Several covariates were included in the adjusted models because they may be related to both vitamin D status and depressive symptoms. These included age, sex, race/ethnicity, BMI, income-to-poverty ratio, and education. BMI was included because body weight may be related to both vitamin D status and depression. Socioeconomic variables such as income and education were included because they can influence diet, health behaviors, access to care, and mental health.

2.5. Statistical analysis

The analysis began with exploratory data analysis. Comparisons of baseline characteristics were made across participants with and without depressive symptoms. Summary statistics included means, SDs, counts, and proportions. Bar charts were used to compare the prevalence of depressive symptoms across vitamin D groups and sleep duration groups.

Logistic regression was used as the main statistical model because the outcome variable was binary. Vitamin D status was the sole predictor in the crude model. The adjusted model included vitamin D status, sleep duration, and covariates. An interaction term between vitamin D status and sleep duration was added in a subsequent model to examine effect modification by sleep duration. The study outcomes are displayed with odds ratios, confidence intervals (95%), and p-values.

3. Results

3.1. Sample characteristics

Table 1 compares the characteristics of participants with and without depressive symptoms. Of the complete-case analytic sample, 416 met the criteria for depressive symptoms, while the remaining 4,328 did not. The average age was similar between the two groups. Participants with depressive symptoms had a mean age of 49.2 years, compared with 49.7 years for those without.

BMI differed more clearly between the two groups. The depressive symptoms group had a higher average BMI than the group without depressive symptoms. Participants with depressive symptoms

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had a mean BMI of 31.6, whereas their non-depressed counterparts had a mean BMI of 29.6.

This suggests that body weight may be an important covariate to consider in the adjusted model.

Vitamin D levels were slightly lower among participants with depressive symptoms. The mean serum vitamin D level was 66.4 nmol/Lamong those with depressive symptoms and 68.5 nmol/L among those without. Sleep duration was also slightly lower among participants with depressive symptoms, , with a mean of 7.5 hours versus 7.6 hours in those without.

The depressive symptoms group also had a higher percentage of female participants, a higher percentage of short sleep, and a slightly higher percentage of vitamin D deficiency. Among participants with depressive symptoms, 60.8% were female, 28.8% had short sleep, and 9.4% were vitamin D deficient. Among participants without depressive symptoms, 50.3% were female, 25.6% had short sleep, and 8.3% were vitamin D deficient.

Table 1. Sample characteristics by depressive symptoms

Characteristic	Depressive symptoms	No depressive symptoms
N	416	4328
Age, mean (SD)	49.2 (17.7)	49.7 (18.4)
BMI, mean (SD)	31.6 (8.1)	29.6 (7.3)
Vitamin D, mean (SD)	66.4 (31.9)	68.5 (31.5)
Sleep hours, mean (SD)	7.5 (2.0)	7.6 (1.6)
Female, %	60.8	50.3
Short sleep, %	28.8	25.6
Vitamin D deficient, %	9.4	8.3

3.2. Depressive symptoms by vitamin D status

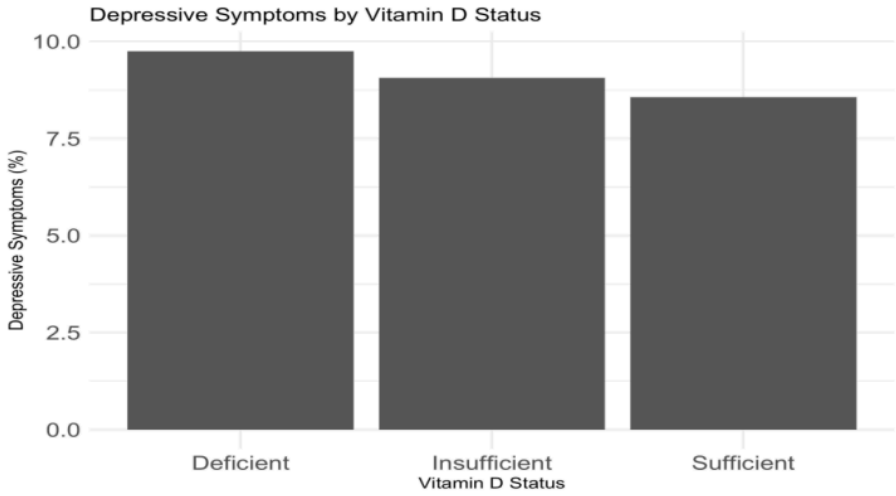

Figure 1. Depressive symptoms by vitamin D status

Figure 1 shows the prevalence of depressive symptoms across vitamin D status groups. An inverse gradient was noted between vitamin D status and depressive symptom prevalence, with rates declining from the deficient to the sufficient group. This descriptive pattern suggests a possible

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negative association between vitamin D status and depressive symptoms: lower vitamin D status may be related to a higher prevalence of depressive symptoms. However, this figure only presents an unadjusted descriptive result. It does not control for age, sex, BMI, income, education, sleep duration, or other possible confounders. To assess the stability of the association in multivariable-adjusted analyses, logistic regression was employed accordingly.

3.3. Logistic regression results

Table 2 presents the crude and adjusted logistic regression results. In the crude model, vitamin D insufficiency was not significantly associated with depressive symptoms compared with vitamin D sufficiency. The crude odds ratio for the insufficient group was 0.97, with a 95% confidence interval from 0.73 to 1.28 and a p-value of 0.848. Vitamin D deficiency also was not statistically significant in the crude model. The crude odds ratio for the deficient group was 1.11, with a 95% confidence interval from 0.73 to 1.64 and a p-value of 0.613.

Vitamin D status showed only a weak and non-significant relationship with depressive symptoms in the fully adjusted model. Compared with the sufficient vitamin D group, the adjusted odds ratio for the insufficient group was 0.91, with a 95% confidence interval from 0.67 to 1.23 and a p-value of 0.559. The adjusted odds ratio for the deficient group was 0.97, with a 95% confidence interval from 0.62 to 1.49 and a p-value of 0.903. Because the confidence intervals included 1 and the p-values were above 0.05, these results do not support a statistically significant independent association between vitamin D status and depressive symptoms after adjustment.

Sleep duration showed a stronger pattern. In comparison with normal sleep, short sleep was linked to elevated odds of depressive symptoms, yielding an adjusted odds ratio of 1.29 (95% CI: 0.99–1.68). The p-value was 0.057, which is slightly above the conventional 0.05 cutoff. Long sleep also showed higher odds of depressive symptoms compared with normal sleep, with an adjusted odds ratio of 1.38 and a 95% confidence interval from 0.97 to 1.92. The p-value was 0.063. Although not statistically significant at the 0.05 level, these results suggest that sleep duration may be more strongly related to depressive symptoms than vitamin D status alone.

Table 2. Logistic regression results for depressive symptoms

Model	Variable	OR (95% CI)
Crude model	Vitamin D: Insufficient	0.97 (0.73, 1.28)
Crude model	Vitamin D: Deficient	1.11 (0.73, 1.64)
Adjusted model	Vitamin D: Insufficient	0.91 (0.67, 1.23)
Adjusted model	Vitamin D: Deficient	0.97 (0.62, 1.49)
Adjusted model	Short sleep	1.29 (0.99, 1.68)
Adjusted model	Long sleep	1.38 (0.97, 1.92)

3.4. Predicted probability by vitamin D and sleep group

Figure 2 shows the predicted probability of depressive symptoms across vitamin D status groups by sleep duration.Depicted in this figure are the results of a logistic regression model that explored the interaction between sleep duration and vitamin D status in relation to depressive symptoms.

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If the lines for different sleep groups are not parallel, this suggests possible effect modification. In the predicted probability plot, the pattern differed across sleep groups. Among participants with vitamin D deficiency, the predicted probability appeared higher in the long sleep group and lower in the normal sleep group. This suggests that the vitamin D–depression association may differ by sleep duration group.

However, the confidence intervals in the predicted probability plot were relatively wide, especially in some vitamin D and sleep duration combinations. Therefore, these results should be interpreted cautiously as exploratory evidence rather than as a strong conclusion. The figure is still useful because it shows why sleep duration may be important to include in the model.

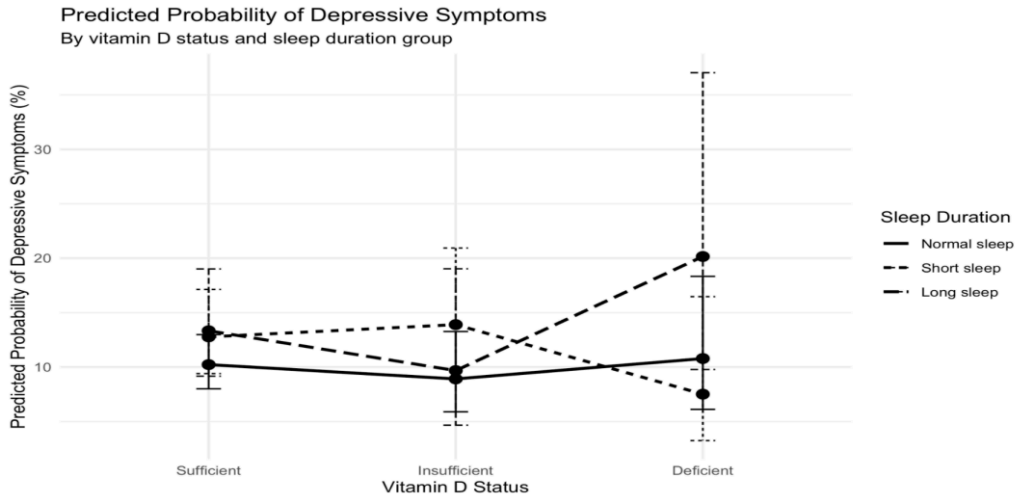

Figure 2. Predicted probability of depressive symptoms by vitamin D and sleep group

4. Discussion

The results were not entirely consistent with the initial hypothesis. Although the descriptive figure suggested that depressive symptoms were more common in the vitamin D deficient group, the adjusted regression model showed that this relationship became weak after covariates were included. Descriptive analyses revealed that the prevalence of depressive symptoms was greatest in the deficient group and least in the sufficient group.This pattern lends weight to the hypothesis that poorer vitamin D status is associated with more depressive symptoms. However, the logistic regression results did not show a statistically significant independent association between vitamin D status and depressive symptoms after adjustment. Both vitamin D insufficiency and deficiency had confidence intervals that included 1, and their p-values were far above 0.05. This suggests that the simple vitamin D–depression relationship may be weaker than expected once demographic, socioeconomic, body weight, and sleep factors are considered.

This finding is important because previous studies on vitamin D and depression have not always produced consistent conclusions [1]. One possible explanation is confounding, as individuals with low vitamin D may differ from those with sufficient levels in terms of BMI, physical activity, diet, income, education, chronic disease, and time spent outdoors. When these variables are not considered, vitamin D may appear more strongly related to depression than it actually is.

Sleep duration appeared to be a more important variable in this analysis. Both short sleep and long sleep showed higher odds of depressive symptoms compared with normal sleep. Although the p-values were slightly above 0.05, the direction and size of the odds ratios suggest that sleep

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duration deserves attention. This supports the idea that sleep should be included when studying nutritional biomarkers and mental health outcomes.

The predicted probability plot also suggested that sleep duration may modify the vitamin D–depression association. In particular, the predicted probability of depressive symptoms was higher in the long sleep group among those with vitamin D deficiency. These results imply that the link between vitamin D levels and depressive symptoms differs by sleep group. However,given the exploratory nature of this analysis and the wide confidence intervals, the interaction result should not be interpreted as definitive.

The main contribution of this study is that it combines a nutritional biomarker, a behavioral factor, and a mental health outcome in the same biostatistical framework. Instead of only asking whether vitamin D is associated with depression, this study also considers whether sleep duration provides important context. This makes the project less redundant than a simple vitamin D–depressive symptoms analysis and more aligned with nutritional epidemiology and applied biostatistics.

From a public health perspective, these results suggest that mental health research should not focus on isolated risk factors alone. Vitamin D status may be one part of a larger health pattern that includes sleep, body weight, socioeconomic status, and lifestyle. Although vitamin D status was not independently significant in this sample, sleep duration showed a stronger pattern and may help explain differences in depressive symptom risk.

5. Conclusion

This study examined serum vitamin D, sleep duration, and depressive symptoms among U.S. adults using public NHANES data. The descriptive evidence indicated that depressive symptom prevalence peaked in the deficient vitamin D group, offering tentative support for an association between lower vitamin D levels and depression. After multivariate adjustment via logistic regression, vitamin D status failed to attain statistical significance in relation to depressive symptoms.

Sleep duration appeared to be more important in the model. Both short sleep and long sleep showed higher odds of depressive symptoms compared with normal sleep, although the p-values were slightly above the conventional 0.05 threshold. The predicted probability analysis also suggested that sleep duration may change the pattern between vitamin D status and depressive symptoms.

Overall, the main conclusion is that the vitamin D–depression relationship should not be studied alone. Sleep duration may provide important context and should be considered in future nutritional epidemiology research. This project demonstrates how a public dataset can be used to combine biomarker data, questionnaire data, and regression modeling to answer a public health question.

This study has several limitations. Because NHANES is cross-sectional, the analysis cannot prove causality. Depressive symptoms and sleep duration were based on questionnaire data, which may involve self-report bias. Complete-case analysis may also reduce the sample size and introduce selection bias. In addition, residual confounding may remain even after adjusting for major covariates. Future studies could use longitudinal data or intervention designs to better assess whether improving vitamin D status and sleep duration reduces depressive symptoms.

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