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Association Between Household Dust Exposure and Sleep Duration: Findings from NHANES 2005–2006

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Abstract

Objective: *Indoor pollutants such as household dust have been suggested as potential contributors to health problems, including sleep disturbances. This study investigates the association between household dust exposure and sleep quality among American adults using data from the National Health and Nutrition Examination Survey (NHANES) between 2005 and 2006.*
Methods: *Data from the NHANES were used in a cross-sectional design. The total dust weight (mg) was the primary exposure variable, and sleep outcomes included self-reported sleep duration, sleep latency, and physician-diagnosed sleep disorders. Data analysis was conducted using univariate and multivariate regression models in STATA with adjustments for confounders.*
Results: *Data on 5,582 adults aged $\geq$18 years regarding sleep duration and 4,893 regarding sleep latency were available. In an adjusted model controlling for age and emotional support, dust weight was significantly associated with a slight decrease in sleep duration (adjusted β = -0.104, 95%CI: -0.206 to -0.002, p = 0.047). In multivariate logistic regression, dust weight showed a significant negative association with sleep duration (adjusted OR = 0.854, 95% CI: 0.740–0.985, p = 0.030), while age and emotional support demonstrated positive associations. Sleep latency showed no significant relationship with dust weight in linear regression analysis, even when controlling for emphysema and PHQ-9 scores (adjusted β = -0.221, 95% CI: -1.394 to 0.952, p = 0.712). Multivariate logistic regression analysis confirmed that there was no significant association between dust weight and sleep latency.*
Conclusion: *This study suggests that household dust exposure modestly affects sleep duration, highlighting the value of improving indoor air quality to enhance sleep health.*

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Introduction

Sleep is essential to human well-being, influences physical and mental health, and significantly con-

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tributes to the overall quality of life. Poor sleep is linked to adverse health outcomes, including obesity, cardiovascular diseases, metabolic disorders, and cognitive decline, as well as heightened risk of anxiety and depression (Hirshkowitz et al., 2015; Liu et al., 2016; Chaput et al., 2018). Despite recommendations for at least seven hours of sleep per night for adults (Watson et al., 2015), over 35% of Americans report insufficient sleep, presenting a major public health concern (Liu et al., 2016).

Beyond individual health, insufficient sleep affects societal productivity and economic stability, with the economic burden of sleep disorders projected to reach $718 billion by 2025 across several OECD countries, including the USA (Hafner et al., 2017). Identifying modifiable factors affecting sleep is critical for developing interventions to improve public health. Although lifestyle factors such as stress, diet, and physical activity are well-documented contributors to poor sleep (Grandner et al., 2017), environmental pollutants, especially indoor allergens found in household dust, warrant further investigation.

Household dust contains particulate matter, allergens, and microbial contaminants that may disrupt sleep by triggering allergic rhinitis (AR), which causes nasal congestion, sneezing, and itchy eyes (Bousquet et al., 2001). These symptoms can prolong the sleep latency and reduce sleep quality (Berson et al., 2020; Romano et al., 2019). While previous studies have linked AR to sleep disorders, few studies have directly examined the impact of household dust on sleep patterns. This study aimed to address this gap by analyzing NHANES 2005-2006 data to explore the association between household dust exposure and sleep quality, providing evidence to guide public health strategies for improving indoor air quality and sleep health.

Materials and Methods

This study employed a cross-sectional analysis of data from the 2005-2006 National Health and Nutrition Examination Survey (NHANES) conducted by the CDC's National Center for Health Statistics to investigate the relationship between household dust exposure and sleep outcomes in U.S. adults. The NHANES provides comprehensive health statistics for a non-institutionalized U.S. population, using an oversampling strategy to represent specific groups, including low-income individuals, adolescents, older adults, and racial/ethnic minorities. Sleep outcomes and household dust exposure data were available for 10,348 adults aged 18 years and older.

The primary exposure variable was the "total dust weight" collected from household dust samples, which was transformed from milligrams (mg) to grams (g). The NHANES 2005-2006 survey collected household dust samples using a standardized vacuuming protocol in the bedrooms of participants, targeting the bed surface and adjacent floor areas. Trained technicians used a Sanitaire™ vacuum with a Mitest™ Dust Collector to ensure consistent sample collection across households. Its potential association with sleep disturbances, sleep duration, and sleep quality was analyzed. Sleep duration was assessed with the question, "How much sleep do you get (hours?)" and was analyzed both continuously and as adequate ($\geq$7 hours) or inadequate (<7 hours) based on American Academy of Sleep Medicine recommendations (Watson et al., 2015). Sleep quality, measured through sleep latency (i.e., the time to fall asleep), was based on responses to "How long does it take to fall asleep?" with latencies of 30 minutes or less considered indicative of good sleep quality (Ohayon et al., 2017).

To account for potential confounding factors, the analysis incorporated a range of covariates, including demographic and socioeconomic characteristics (e.g., age, sex, race, marital status, and annual family income), behavioral factors (e.g., current smoking), health-related conditions (e.g., asthma, chronic bronchitis), and psychosocial attributes. These covariates were chosen based on their associations with sleep disturbances. Nasal symptom scores and additional sleep data (e.g., polysomnography, snoring scores, and Epworth Sleepiness Scale) were not available in this dataset. Covariates that showed statistical significance in univariate analysis ($P < 0.20$) were included in the multivariate models. For the statistical analysis, adult participants with available sleep outcome data were included. Descriptive statistics were presented as means and standard deviations for continuous variables and frequencies for categorical variables. Linear regression models were used to examine sleep duration and latency as continuous variables, with covariates selected based on a literature review and a significance threshold of $p < 0.05$ for multivariate inclusion. Results were reported as beta coefficients (β). Additionally, secondary analyses categorized sleep outcomes as adequate/inadequate and sound/not good, with group differences analyzed using chi-square tests for categorical variables and unpaired t-tests for continuous variables. Logistic regression models were employed to examine associations with categorized sleep outcomes, with results reported as odds ratios (OR) and 95% confidence intervals. For Adequate Sleep Duration (>7 hours), Receiving Operating Curves (ROC) to detect the optimal HouseHold Dust cutoff will be performed. All analyses were conducted using Stata 18 (StataCorp LLC, College Station, TX, USA).

Results

For this cross-sectional analysis, of the initial 10,348 participants, 5,582 adults (aged 18 and older) were included to assess sleep duration and 4,893 adults to evaluate sleep latency, both sampled from the NHANES 2005–2006 dataset. Participants were excluded from the final analysis owing to missing data on key variables, including sleep outcomes, household dust exposure, or covariates. Missing data were addressed using a complete-case analysis approach, ensuring that only participants with complete data on the relevant variables were included. Sensitivity analyses confirmed that exclusion did not introduce significant bias.

The mean age was 45.2 years (SD ± 20.3), and 52.0% were female. The majority (48.2%) were identified as Non-Hispanic White. Among the participants, 31.3% were categorized as having inadequate sleep duration (fewer than 7 hours per night), and 17.3% reported poor sleep quality, defined by a sleep latency of 30 min or more. The key participant characteristics, categorized by sleep outcomes, are detailed in Table 1.

Association Between Household Dust and Sleep Duration

Sleep duration was measured as a continuous variable in hours. In the univariate linear regression analysis, dust weight (g) did not significantly predict sleep duration (β = -0.030, 95% CI: -0.091 to 0.031, p = 0.33). Figure 1 illustrates a scatter plot depicting the correlation between sleep duration and dust weight, which did not reveal a significant association. Logistic regression analysis, categorizing sleep duration as adequate or inadequate, also showed no association with dust weight (OR = 0.941, 95% CI: 0.847–1.044, p = 0.251). These findings are summarized in Table 2 (linear regression results) and Table 3 (logistic regression results).

In the multivariate linear regression adjusted for age and emotional support, dust weight showed a slight but statistically significant negative association with sleep duration (adjusted β = -0.104, 95% CI: -0.206 to -0.002, p = 0.047). This implies that each additional gram of dust is associated with a reduction in sleep duration of 6.3 minutes. While statistically significant, this effect size is small and may have limited clinical relevance, as even small reductions in sleep may not have a meaningful impact on overall health outcomes. Age and emotional support were positively correlated with sleep duration in the adjusted model, suggesting that older individuals and those receiving greater emotional support tend to have longer sleep durations, as detailed in Table 2.

Multivariate logistic regression (summarized in Table 3) mirrored these results, showing a slight negative association between dust weight and adequate sleep (adjusted OR = 0.854, 95% CI: 0.740 to 0.985, p = 0.030). Age and emotional support retained positive associations (adjusted OR = 1.009 and 1.744, respectively).

Association Between Household Dust and Sleep Latency

For the binary outcome of sleep duration, an ROC curve was performed using Total Dust Weight to predict the best cutoff point (Figure 3). The Area Under the Curve (AUC) is 0.4938, indicating poor discrimination between adequate and inadequate sleep duration. An optimal cutoff point of 760.05 mg of total dust weight was identified, corresponding to a sensitivity of 0.54 and a specificity of 0.45.

Discussion

The study identified a weak but significant negative association between household dust weight and sleep duration in a multivariate linear regression model adjusted for age and emotional support. The link between indoor dust, allergens, and respiratory symptoms, which disrupt sleep quality and duration, was previously established (Aggarwal et al., 2023; DeVries et al., 2018; Fujimura et al., 2013). Although another cross-sectional study associated household dust with sleep disturbances (Leger et al., 2017), our model shows only a modest relationship with sleep duration, and the overall results were not clinically relevant.

We hypothesized that the lack of key covariates in our model, particularly rhinitis symptoms and sleep quality metrics (e.g., polysomnography, snoring scores, sleep quality scores), limited our ability to build a comprehensive model addressing sleep duration. Other important covariates, such as noise exposure and the presence of pets, were not evaluated and might also affect sleep outcomes.

Household dust may impact sleep through several biological and environmental mechanisms. Dust often contains a complex mixture of allergens, pollutants, and microbial components that can trigger inflammatory responses, particularly in the respiratory system, leading to nasal congestion, airway irritation, and asthma, disrupting sleep quality and duration. Additionally, disrupted sleep also increases systemic inflammation. This indeed leads to a cycle of respiratory inflammation that is further enhanced by household dust and impacts further sleep (Yang, 2024)

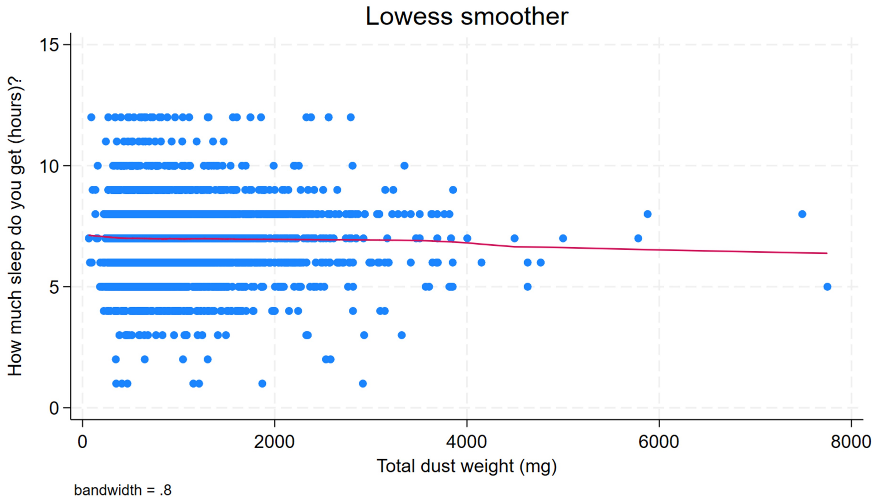

Figure 1: *Scatter plot of sleep duration vs. dust weight.*

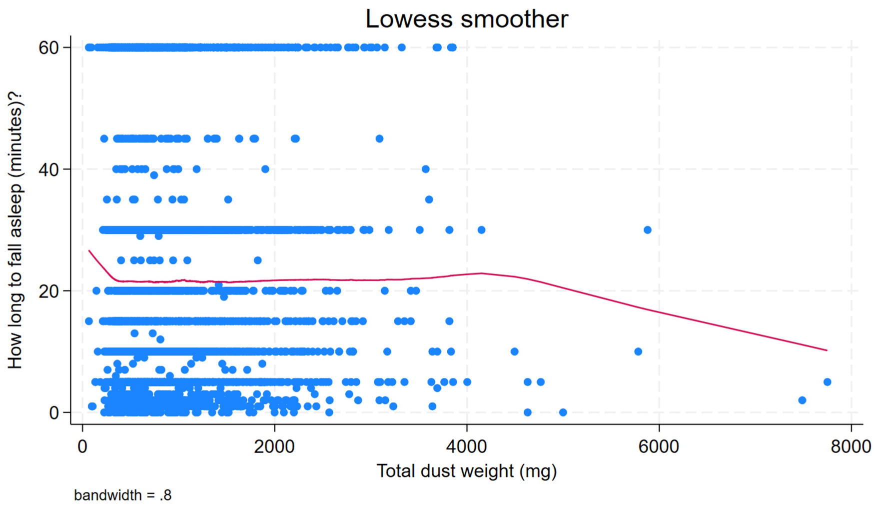

Figure 2: *Scatter plot of sleep latency vs. dust weight.*

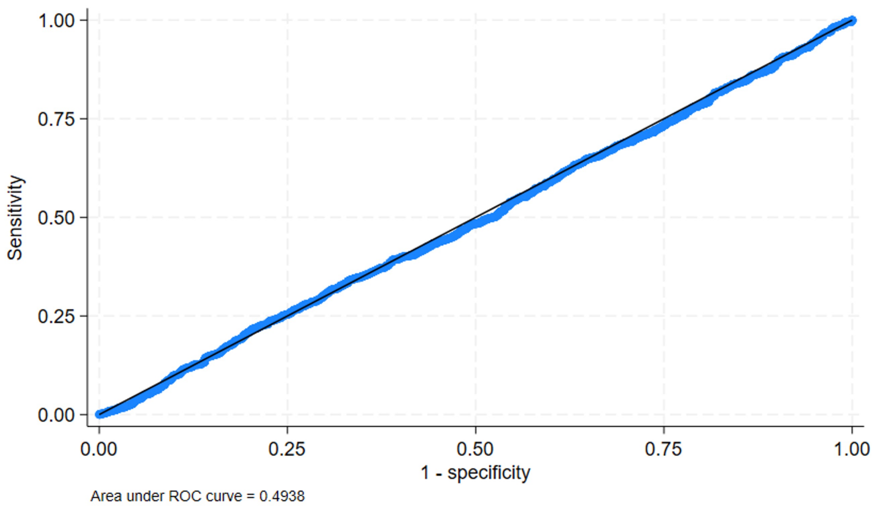

Figure 3: *Receiver Operating Characteristic (ROC) curve for household dust weight predicting adequate sleep duration.*

Participants' characteristics		Adequate Sleep Duration			Good Sleep Latency		
		No, n = 1747	Yes, n = 3835	p	No, n = 851	Yes, n = 4042	p
Age, years, mean (SD)		45.06 (19.88)	45.25 (20.46)	0.75	44.41 (20.28)	45.24 (20.24)	0.27
Sex, n (%)	Male	884 (48.31)	1831 (47.98)	0.05	394 (46.30)	1964 (48.59)	0.22
	Female	903 (51.69)	1985 (52.02)		457 (53.70)	2078 (51.41)	
Ethnicity, n (%)	Non-Hispanic White	794 (45.45)	1839 (48.19)	0.27	387 (45.48)	1933 (47.82)	0.50
	Non-Hispanic Black	447 (25.59)	894 (23.43)		212 (24.91)	972 (24.05)	
	Other Hispanic	53 (3.03)	118 (3.09)		26 (3.06)	116 (2.87)	
	Mexican American	373 (21.35)	812 (21.28)		183 (21.50)	863 (21.35)	
	Other races	80 (4.58)	153 (4.01)		43 (5.05)	158 (3.91)	
Marital status, n (%)	Married, cohabiting	988 (56.65)	2171 (56.95)	0.76	472 (55.53)	2296 (56.87)	0.25
	Widowed, divorced, separated	353 (20.24)	741 (19.44)		160 (18.82)	810 (20.06)	
	Never married	403 (23.11)	900 (23.61)		218 (25.65)	931 (23.06)	
Family PIR, n (%)	High income	642 (38.98)	1463 (40.39)	0.77	296 (36.27)	1540 (40.42)	0.10
	Middle income	263 (15.97)	552 (15.24)		138 (16.91)	580 (15.22)	
	Near poor income	421 (25.56)	902 (24.90)		206 (25.25)	961 (25.22)	
	Poor income	321 (19.49)	705 (19.46)		176 (21.57)	729 (19.13)	
Smoking, n (%)		455 (60.75)	983 (61.48)	0.74	222 (61.16)	1050 (61.40)	0.93
Asthma, n (%)		231 (13.24)	516 (13.55)	0.75	119 (13.98)	522 (12.94)	0.41
Emphysema, n (%)		34 (2.17)	64 (1.88)	0.50	28 (3.69)	58 (1.61)	<0.001
Chronic bronchitis, n (%)		100 (6.38)	190 (5.59)	0.27	58 (7.68)	193 (5.36)	0.01
PHQ9, mean (SD)		3.07 (4.14)	2.74 (3.96)	0.008	3.37 (4.28)	2.75 (3.96)	0.002
Emotional support, n (%)		860 (90.43)	1926 (93.31)	0.005	409 (92.53)	2036 (92.13)	0.77
Total dust weight, mg, mean (SD)		996.03 (682.55)	970.25 (625.33)	0.25	961.07 (649.31)	984.11 (654.43)	0.44
Type of floor covering, n (%)	Smooth surface	124 (10.67)	295 (11.36)	0.37	69 (12.00)	305 (11.16)	0.57
	Low pile carpet	877 (75.47)	1927 (74.61)		415 (72.17)	2043 (74.75)	
	High pile carpet	126 (10.84)	268 (10.32)		69 (12.00)	351 (10.61)	
	Combination	35 (3.01)	106 (4.08)		22 (3.83)	125 (3.78)	
Room humidity, %, mean (SD)		51.82 (12.48)	52.41 (12.43)	0.17	52.74 (12.46)	52.06 (12.36)	0.23
Room temperature, F, mean (SD)		73.88 (5.28)	73.80 (5.52)	0.66	73.55 (5.57)	73.92 (5.37)	0.14

Table 1: *Sample size (n) and participant's characteristics.*

Model	Variables	Coefficient (β)	95% CI	p-value	Model p-value	Adjusted R2
Sleep duration						
Model 1 (crude)	Dust weight (g)	-0.0302	-0.0909 to 0.0305	0.329	0.329	-0.0000
Model 2 (adjusted)	Dust weight (g)	-0.0282	-0.0892 to 0.0327	0.364	0.475	-1
	Age	0.0006	-0.0011 to 0.00234	0.463		
Model 3 (adjusted)	Dust weight (g)	-0.1040	-0.2064 to -0.0015	0.047	<0.001	0.0135
	Age	0.0082	0.0031 to 0.0132	0.001		
	Emotional support	0.4403	0.1926 to 0.6880	0.001		
Sleep latency						
Model 1 (crude)	Dust weight (g)	0.0359	-0.7499 to 0.8217	0.929	0.929	-0.0002
Model 2 (adjusted)	Dust weight (g)	-0.3937	-1.4734 to 0.6859	0.475	0.032	0.0016
	Emphysema	63.869	1.5022 to 11.2715	0.010		
Model 3 (adjusted)	Dust weight (g)	-0.2210	-1.3942 to 0.9522	0.712	0.027	0.0023
	Emphysema	52.213	0.2253 to 10.2172	0.041		
	PHQ9	0.1763	0.0047 to 0.3480	0.044		

β: beta coefficient; CI: confidence interval

Table 2: *Linear regression analyses.*

Model	Variables	OR	95% CI	*p*-value	Model p-value
Sleep duration					
Model 1 (crude)	Dust weight (g)	0.941	0.847 to 1.044	0.251	0.253
Model 2 (adjusted)	Dust weight (g)	0.947	0.852 to 1.052	0.308	0.324
	Age	1.002	0.998 to 1.005	0.330	
Model 3 (adjusted)	Dust weight (g)	0.854	0.740 to 0.985	0.030	<0.001
	Age	1.009	1.002 to 1.016	0.011	
	Emotional support	1.744	1.252 to 2.430	0.001	
Sleep latency					
Model 1 (crude)	Dust weight (g)	0.946	0.822 to 1.088	0.438	0.433
Model 2 (adjusted)	Dust weight (g)	0.918	0.787 to 1.072	0.280	0.007
	Emphysema	2.443	1.417 to 4.214	0.001	
Model 3 (adjusted)	Dust weight (g)	0.908	0.766 to 1.076	0.266	0.007
	Emphysema	2.165	1.221 to 3.840	0.008	
	PHQ9	1.024	1.001 to 1.047	0.038	

CI: confidence interval; OR: odds ratio

Table 3: *Logistic regression analyses.*

Strengths and Limitations

A notable strength of this study is its use of the NHANES dataset, which is large and nationally representative. Although the oversampling strategy limits its generalizability, our large sample size increases the external validity beyond the U.S. adult population. Additionally, the study's comprehensive control of diverse covariates enabled a more thorough examination of the relationship between household dust and sleep.

However, it is important to acknowledge several limitations. The study's cross-sectional design restricts causal inferences, making it unclear whether dust exposure is associated with sleep disturbances or if those with sleep issues engage in behaviors that increase dust accumulation. The reliance on self-reported sleep data may introduce reporting bias, as subjective assessments can skew results.

Additionally, the absence of detailed frequency distributions for dust weight and the exclusion of participants with missing data may have impacted the precision and robustness of the results.

These findings contribute to a growing body of evidence that suggests household dust is associated with sleep quality. Future studies should explore causal relationships through longitudinal designs and incorporate objective sleep assessments. Moreover, investigating additional environmental and behavioral factors would help refine our understanding of how household environments impact sleep health.

Conclusion

Although the observed effects were modest, this study offers preliminary evidence that household dust exposure may impact sleep duration and quality. While the model has limited association, the findings underscore the potential benefits of enhancing indoor air quality as part of a broader strategy for improving sleep health. Future research should clarify the causal pathways between dust exposure and sleep disturbances using longitudinal designs and examine the interaction between environmental, behavioral, and psychosocial factors. Public health initiatives focused on improving indoor air quality, such as promoting cleaner indoor environments through educational campaigns or encouraging air purifiers, could provide practical means to enhance sleep outcomes.

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Conflicts of Interest

The authors declare no conflict of interest.

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