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The association of sedentary time with sleep disturbances among the US population, 2005 to 2014

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Abstract

Background Sleep problems increase the risk of premature illness and death. We evaluated the association between sedentary time and sleep disturbances.

Methods A cross-sectional analysis of the US nationally representative data of 21,414 adults (aged >= 18 years) from National Health and Nutrition Examination Survey (NHANES) (2005–2014) was performed. The data of sleep disturbances were assessed using NHANES questionnaire results, which included the question, "{Have you/has sp} ever been told by a doctor or other health professional that {you have/s/he has} a sleep disorder?". All participants were stratified by quartiles of sedentary behavior distribution, which was the explanatory variable (sedentary time quartile cut points: Q1, 0 <= Q1 < 3 h; Q2, 3 <= Q2 < 5 h; Q3, 5 <= Q3 < 8 h; Q4, 8 <= Q4 < 20 h). We used multivariable logistic regression and the restricted cubic splines (RCS) model to assess the relationship between sedentary time and sleep disturbances.

Results In the unadjusted multivariable logistic regression model (crude model), there was a demonstrated tendency for the odds of sleep disturbances to increase with the sedentary time (Q1 as reference, Q2: OR, 1.31 [95% CI 1.09–1.58] $P = 0.005$; Q3: OR, 1.62 [95% CI 1.39–1.88] $P < 0.001$; Q4: OR, 1.75 [95% CI 1.48–2.06] $P < 0.001$; P for trend < 0.001). In the adjusted model 4, adjustment for gender, age, marital type, education type, race, family poverty index ratio, waist circumference, recreational type, smoke status, drink status, diabetes mellitus status, cardiovascular disease status, sleep duration type, body mass index, the OR in Q2 subgroup didn't significantly increase (Q1 as reference. Q2: OR, 1.18 [95% CI 0.96–1.44] $P = 0.1$). However, the ORs in Q3 and Q4 (Q3: OR, 1.35 [95% CI 1.14–1.59] $P < 0.001$; Q4: OR, 1.45 [95% CI 1.21–1.75] $P < 0.001$) both revealed that the risk of sleep disturbances increased with increasing sedentary time, P for trend < 0.001. The unadjusted RCS model revealed that the risk of sleep disturbances increased non-linearly with increasing sedentary time for total participants (P for non-linearity < 0.001). After adjusting for all covariates, the RCS results revealed that the risk of sleep disturbances increased non-linearly with increasing sedentary time for total participants (P for non-linearity = 0.012).

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Conclusions This study suggested that the longer sedentary time was strongly associated with the sleep disturbances. The protective effect of recreational activities on sleep disturbance, has not been significantly demonstrated.

Keywords Sedentary time, Sleep disturbances, Multivariable logistics regression, RCS (restricted cubic spline)

Introduction

Sedentary time is a significant public health concern, and there has been an observed increase in the prevalence of total sitting time among both adolescents and adults in the US population from 2001 to 2016 [1]. Previous research indicated that prolonged sedentary behavior is associated with a higher risk of all-cause mortality [2, 3], obesity [4], cardiovascular disease [5], cancer [6], diabetes [7], and stroke [8]. Numerous previous studies have shown that severe sedentary behavior is associated with an increased risk of sleep disturbances, and longer sedentary time is strongly linked with sleep disturbances. Additionally, vigorous physical activity (PA) has been shown to be associated with a lower risk of sleep disturbances [9–12].

Sleep disturbances have been identified as a public health epidemic by the Center for Disease Control. There is currently a high incidence of sleep disturbances worldwide. More than one third of respondents in the U.S. [13], 40% Canadian adults [14] and 50% working adults in Malaysia [15] reported sleep disturbances based on r self-report. The past decade has seen sleep health become a focal point in epidemiological and health research, with studies showing that sleep disturbances can impact immune functions and increase multisystem biological risk through the elevation of proinflammatory markers, systemic inflammation, and immune dysfunctions [16, 17]. Sleep disturbances is associated with an increased risk of dementia [18] and cognitive decline in later life [19], as well as impacting glycemic control in adults with T2DM [20].

Sleep plays a critical role in promoting overall health. The most commonly used interventions for sleep disorders are stress management and relaxation exercises, stimulus control, sleep hygiene, and PA. The results of reviews indicate that acute and regular PA have positive effects on numerous sleep outcomes [21, 22]. Qi Feng et al. suggested that high levels of PA and low screen time were independently associated with significantly lower risk for poor sleep quality and depression among Chinese college freshmen [23]. Seth A Creasy et al. also suggested that longer sedentary time is associated with shorter sleep duration and poorer sleep quality. Moreover, higher levels of PA have been suggested as beneficial for sleep quality in postmenopausal women [24].

To the best of our knowledge, there is limited research, particularly in large-scale national studies, that has investigated the relationship between sleep disturbances and sedentary behavior. Most previous studies have relied on self-reported sleep disorders, whereas this study represents the first attempt to investigate the correlation among individuals diagnosed with sleep disorders by medical professionals, thus providing research evidence that is more reflective of real-world conditions. This cross-sectional study aimed to (I) explore the association between sedentary behavior and sleep disturbances based on data from the National Health and Nutrition Examination Survey; (II) adjust for various potential confounders, using multiple models to compare trends in the relationship between sedentary time and sleep disturbances; and (III) investigate whether recreational activities levels affected the associations between sedentary behavior and sleep disturbances.

Methods

Study population

The original data for this cross-sectional study was 49,880 participants from 5 discrete 2-year cycles of the continuous National Health and Nutrition Examination Survey (NHANES) (2005/2006, 2007/2008, 2009/2010, 2011/2012, 2013/2014) in America. According to the exclusion criteria, the study excluded 17,836 subjects who did not have self-reported information about sleep disorders, 121 participants with no information on sedentary behavior and sedentary time, and 1,906 subjects younger than 18 years old. Moreover, we excluded 8,603 participants who lacked covariates data, including those with no education data ($n=1,850$), marital data ($n=14$), family poverty index ratio (PIR) data ($n=2,327$), smoking data ($n=13$), body mass index (BMI) data ($n=1,182$), waist circumference data ($n=1,065$), diabetes mellitus (DM) data ($n=524$), drink data ($n=1,627$), cardiovascular disease (CVD) data ($n=1$). The remaining 21,414 subjects with available data were included in the statistical analysis. A total of 1,816 subjects were added to sleep disorder group, with questionnaire results indicating that they had been diagnosed with sleep disturbances by doctors. Figure 1 illustrates the flowchart of participant selection.

Measures

Outcomes: sleep disturbances

The outcome, sleep disturbances, was assessed by the NHANES questionnaire sq060 "{Have you/has sp} ever been told by a doctor or other health professional that {you have/s/he has} a sleep disorder?". The response categories of this question were "Yes," "No," "Refused," and

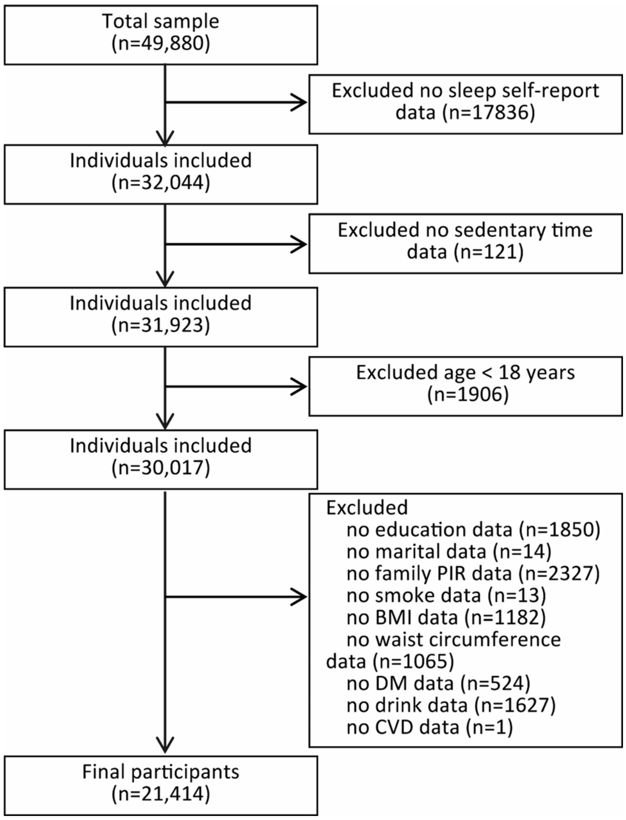

Fig. 1 Flowchart of the study design and participants excluded from the study. PIR, poverty index ratio; BMI, Body Mass Index; DM, diabetes mellitus; CVD, cardiovascular disease

"Do not know." For participants who responded with "Do not know" or "Refused," their data was considered as missing values.

Exposure: recreational activities and sedentary behavior

The data on recreational activities and sedentary behavior were self-reported in the NHANES by the Physical Activity Questionnaire [10].

In the 2005–2006 survey cycle, the question of the Physical Activity Questionnaire was "Have you done any vigorous activity over past 30 days?" and "Have you done any moderate activity over past 30 days?". In the 2007–2014 survey cycle, the corresponding question has been changed to "In a typical week, do you do any vigorous-intensity sports, fitness, or recreational activities that cause large increases in breathing or heart rate like running or basketball for at least 10 min continuously?" and "In a typical week, do you do any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, bicycling, swimming, or volleyball for at least 10 min continuously?" [10].

The sedentary behavior was defined as the time spent sitting on a typical day, including sitting at a desk, traveling in a car or bus, or train, reading, playing cards, watching TV or videos, or using a computer, but it did not include the time spent sleeping [10]. In the 2005–2006 survey cycle, the question was "Over the past 30 days, on average about how many hours per day did you sit and watch television or videos" and "Over the past 30 days, on average about how many hours per day did you use a computer or play computer games" with options of None/less than 1 h/1 hour/2 hours/3 hours/4 hours/5 hours or more/Refused/Don't know. The sedentary time data was a total duration of both aspects. In the 2007–2014 survey cycles, the sedentary time data referred to sitting or reclining at work, at home, or at school. The corresponding question was "How much time (do you/does SP) usually spend sitting or reclining on a typical day?" with options of minutes/Refused/Don't know [1].

Covariates

In this study, sociodemographic and lifestyle factors (gender, age, marital ststus, education level, race, PIR, waist circumference, recreational type, smoking status, drinking status, diabetes status, CVD status, sleep duration, BMI) were collected as potential confounding factors (Supplementary Table S2 "Sleep disturbance-related pathways overview illustrated in the directed acyclic graph (DAG)").

According to the World Health Organization recommendations, waist circumference is classified as follows: <= 94 cm for male and <=80 cm for female into normal group, and waist circumferences above these thresholds into high group. Education status was classified into three groups: 9-11th grade or less group (includes 12th grade with no diploma), high school graduated/equal group, and college graduate/above/equal group. Marital status was categorized into three groups: those living with a partner or married, those who were divorced, separated, or widowed, and those who had never been married. Race was classified into four groups, including the white group, black group, Mexican American group and the other racial groups. Non-Hispanic white was classified into white group, non-Hispanic black was classified into black group, Mexican American was classified into Mexican American group. PIR classification was low ($PIR<1.0$), middle ($1.0\leq PIR\leq 3.0$) and high ($PIR>3.0$). BMI was classified as follows: normal ($BMI<25$ kg/m^2), overweight (25 kg/m^2 $\leq$ $BMI<30$ kg/m^2), and obese ($BMI\geq 30$ kg/m^2). Smoking status and alcohol use status were categorized based on responses to questionnaires about cigarette and alcohol consumption, respectively. 'Never smokers' were defined as individuals who have never smoked. 'Former smokers' were those who had smoked at least 100 cigarettes in their lifetime but do not smoke now. 'Current smokers' were defined as subjects who have smoked at least 100 cigarettes in their lifetime and continue to smoke. 'Never drinkers' referred to participants who had never consumed alcohol in their lifetime. 'Former drinkers' were those who had consumed alcohol regularly in the past but do not drink now. 'Current drinkers' were participants who are consuming alcohol weekly at present.

Statistical analysis

All data were based on population-weighted analysis, and the details of weights were explained in NHANES' introduction. In view of the complex multistage (strata and cluster) sampling design of the NHANES, the R 4.3.3 version (survey Version 4.4-1, rms Version 6.8-0) were used to conduct the weighted analysis. Sample weights were reweighted to merge 10 years of total survey data from the NHANES 2005 to 2014. The merged weights were represented as WT05-14=(1/5) × WTINT2YR05–06 + (1/5) × WTINT2YR07–08 + (1/5) × WTINT2YR09–10+(1/5) × WTINT2YR11–12+ (1/5) × WTINT2YR13–14.

All numerical variables were shown as mean ± standard error. Baseline characteristics between the sleep disturbances group and the non-sleep disturbances group were compared using the Wilcoxon rank-sum test for continuous variables in complex survey samples, and the chi-squared test with Rao & Scott's second-order correction for categorical variables. A P-value < 0.05 was considered statistically significant for all analyses.

Stratified analyses were performed based on age, sex, marital status, education level, race, PIR, BMI, waist circumference, type of recreation, smoking status, type of drinking, history of diabetes, history of heart disease, and sleep duration. The covariates, including recreation type, PIR category, smoking status, drinking status, and sleep duration type, were evaluated for interactions. For the complex sample data, the significance of the interactions was assessed using the svyglm function of R, with a threshold for significance set at $P < 0.1$.

All participants were categorized into quartiles based on their sedentary time, with the following cut points: Q1, 0<=Q1<3 h; Q2, 3<=Q2<5 h; Q3, 5<=Q3<8 h; Q4, 8<=Q4<20 h. The sedentary time was entered into the models as continuous variables and categorical variables (with the lowest sedentary time quartile as a reference group). The weighted multivariate logistic regression analysis was performed to examine the association between sedentary behavior and sleep disturbances, with 95% confidence intervals (CI) and odds ratio (OR) calculated. The P values for trend were obtained through the use of the quartile level as an ordinal variable. Five multivariate models were constructed to explore the association between sedentary behavior and sleep disturbances, including crude model (unadjusted), adjusted model 1 (adjusted for gender, age type and BMI type), adjusted model 2 (only adjusted for recreational type), adjusted model 3 (adjusted for recreational type, PIR type, smoke status, drink status, sleep duration type, all P for interaction < 0.1), adjusted model 4 (adjusted for gender, age, marital type, education type, race, PIR, waist circumference, recreational type, smoke status, drink status, diabetes status, CVD status, sleep duration type, BMI).

A Restricted Cubic Spline (RCS) model was employed to investigate the non-linear relationship between the sedentary time and sleep disturbances. The adjustment models included potential confounding variables such as gender, age group, marital type, education type, race, PRI, waist circumference, smoke status, drink status, DM status, CVD status, sleep duration type, BMI group. The significance of non-linear effects was assessed using a threshold of P for non-linearity < 0.05.

Results

A tatal of 21,414 participants were eligible for our final analysis (Fig. 1). The baseline characteristics and demographic information of participants (weighted data) were shown in Table 1. The weighted prevalence of sleep disturbances symptoms was 8.60%. The weighted prevalence of sleep disturbances group was higher among men, constituting 53.45% of all participants with sleep disturbances. The average sleep duration for all participants was 6.88 ± 0.01 h. In contrast, participants in the sleep disturbances group had an average sleep duration of 6.48 ± 0.05 h, which was significantly shorter than that of participants without sleep disturbances ($P < 0.0001$). The mean of sedentary time of participants in the sleep disturbances group was 6.3 ± 0.11 h, which was significantly higher than that of participants without sleep disturbances with 5.6 ± 0.06 h ($P < 0.0001$). Additionally, the weighted prevalence of sleep disturbances significantly varied across different categories, including age, sex, race, BMI, marital status, waist circumference, recreational activities, smoking status, diabetes status, CVD status, and alcohol consumption status ($P < 0.05$) (Table 1). The baseline characteristics and demographic information of participants (unweighted data) were shown in Table S1.

The stratified analysis results were shown in Table 2. The P-value for trend was less than 0.05 in most subgroups, except for the never married group, other races, BMI category of 25.0 to 29.9 kg/m², normal waist circumference, never drinkers, the CVD group, those engaging in vigorous recreational activities, and the long sleep duration group (>9 h). Five covariates showing statistical significance were identified and assessed for interactions through variable interaction testing, including recreation type, PIR category, smoking status, drinking status, and sleep duration type (with P values for interaction less than 0.1) (Table 2).

Table 1 Baseline characteristics and Demographic Information of Participants (Weighted Data)

Variable	Overall, N = 173,603,777[1]	Non-sleep disturbances, N = 158,680,666 (91.4%)[1]	Sleep disturbances, N = 14,923,111 (8.60%)[1]	P-value[2]
Age (yr)	47.04 (0.29)	46.66 (0.30)	51.09 (0.33)	< 0.001
Body Mass Index (kg/m^2)	28.8 (0.08)	28.4 (0.08)	32.6 (0.25)	< 0.001
Sedentary behaviour (h/day)	5.6 (0.06)	5.6 (0.06)	6.3 (0.11)	< 0.001
Sleep duration (h/day)	6.88 (0.01)	6.92 (0.01)	6.48 (0.05)	< 0.001
Gender, n (%)				0.007
Male	85,975,703 (49.52(0.003)%)	77,999,127 (49.16(0.004)%)	7,976,576 (53.45(0.015)%)	
Female	87,628,074 (50.48(0.003)%)	80,681,539 (50.84(0.004)%)	6,946,535 (46.55(0.015)%)	
Age group, n (%)				< 0.001
< 45	79,742,528 (45.93(0.008)%)	74,941,031 (47.23(0.008)%)	4,801,496 (32.18(0.013)%)	
45–65	64,452,494 (37.13(0.006)%)	57,156,377 (36.02(0.006)%)	7,296,117 (48.89(0.015)%)	
> 65	29,408,755 (16.94(0.005)%)	26,583,258 (16.75(0.005)%)	2,825,497 (18.93(0.010)%)	
Marital status, n (%)				< 0.001
Married/living with partner	111,318,716 (64.12(0.008)%)	101,556,441 (64.00(0.008)%)	9,762,276 (65.42(0.014)%)	
Divorced/separated/widowed	31,847,542 (18.35(0.004)%)	28,464,216 (17.94(0.004)%)	3,383,326 (22.67(0.012)%)	
Never married	30,437,518 (17.53(0.007)%)	28,660,009 (18.06(0.008)%)	1,777,509 (11.91(0.010)%)	
Education level, n (%)				0.18
College Graduate/above/equal	105,604,165 (60.83(0.010)%)	96,444,379 (60.78(0.011)%)	9,159,786 (61.38(0.017)%)	
High school graduated/equal	39,729,909 (22.89(0.006)%)	36,128,532 (22.77(0.006)%)	3,601,377 (24.13(0.015)%)	
9-11th grade or less	28,269,703 (16.28(0.007)%)	26,107,756 (16.45(0.007)%)	2,161,947 (14.49(0.010)%)	
Race, n (%)				< 0.001
White	122,639,449 (70.64(0.015)%)	111,278,519 (70.13(0.015)%)	11,360,930 (76.13(0.017)%)	
Black	18,552,132 (10.69(0.008)%)	17,061,482 (10.75(0.008)%)	1,490,650 (9.99(0.009)%)	
Mexican American	13,435,548 (7.74(0.007)%)	12,741,272 (8.03(0.007)%)	694,276 (4.65(0.007)%)	
Others race	18,976,647 (10.93(0.006)%)	17,599,394 (11.091(0.006)%)	1,377,254 (9.23(0.008)%)	
Family PIR group, n (%)				0.36
Low (< 1.0)	23,788,321 (13.70(0.006)%)	21,610,195 (13.62(0.006)%)	2,178,126 (14.60(0.012)%)	
Middle (1.0–3.0)	61,541,379 (35.45(0.008)%)	56,097,414 (35.35(0.008)%)	5,443,965 (36.48(0.015)%)	
High (> 3.0)	88,274,077 (50.85(0.011)%)	80,973,058 (51.03(0.011)%)	7,301,019 (48.92(0.017)%)	
BMI group, n (%)				< 0.001
< 25.0 kg/m^2	53,499,579 (30.82(0.006)%)	51,099,770 (32.20(0.006)%)	2,399,809 (16.08(0.010)%)	
25.0–29.9 kg/m^2	58,368,113 (33.62(0.005)%)	54,677,525 (34.46(0.005)%)	3,690,587 (24.73(0.015)%)	
>= 30 kg/m^2	61,736,085 (35.56(0.005)%)	52,903,371 (33.34(0.006)%)	8,832,714 (59.19(0.016)%)	
Waist circumference type, n (%)				< 0.001
Normal (< = 94formaleand < = 80forfemale)	43,406,671 (25.00(0.007)%)	41,568,892 (26.20(0.007)%)	1,837,779 (12.32(0.010)%)	
High	130,197,106 (75.00(0.007)%)	117,111,775 (73.80(0.007)%)	13,085,332 (87.68(0.010)%)	
Recreational type, n (%)				< 0.001
No activities	73,941,047 (42.59(0.009)%)	65,819,796 (41.48(0.009)%)	8,121,251 (54.42(0.016)%)	
Moderate	51,506,054 (29.67(0.006)%)	47,459,996 (29.910(0.006)%)	4,046,058 (27.11(0.013)%)	
Vigorous	48,156,676 (27.74(0.008)%)	45,400,875 (28.61(0.009)%)	2,755,801 (18.47(0.012)%)	
Smoking status, n (%)				< 0.001
Never smoker	93,344,846 (53.77(0.007)%)	86,867,812 (54.74(0.007)%)	6,477,034 (43.40(0.017)%)	

Table 1 (continued)

Variable	Overall, N = 173,603,777[1]	Non-sleep disturbances, N = 158,680,666 (91.4%)[1]	Sleep disturbances, N = 14,923,111 (8.60%)[1]	P-value[2]
Former smoker	43,087,953 (24.82(0.005)%)	38,283,452 (24.13(0.006)%)	4,804,501 (32.20(0.014)%)	
Current smoker	37,170,977 (21.41(0.005)%)	33,529,402 (21.13(0.005)%)	3,641,575 (24.40(0.012)%)	
Drinking status, n (%)				< 0.001
Never drinker	18,116,421 (10.44(0.006)%)	16,693,361 (10.52(0.005)%)	1,423,061 (9.54(0.011)%)	
Former drinker	26,745,635 (15.41(0.005)%)	23,356,222 (14.72(0.005)%)	3,389,413 (22.71(0.014)%)	
Current drinker	128,741,720(74.15(0.009)%)	118,631,084 (74.76(0.008)%)	10,110,637 (67.75(0.019)%)	
Diabetes status, n (%)				< 0.001
No diabetes	136,880,690 (78.85(0.005)%)	126,912,940 (79.98(0.005)%)	9,967,749 (66.79(0.014)%)	
Diabetes/Prediabetes	36,723,087 (21.15(0.005)%)	31,767,726 (20.02(0.005)%)	4,955,361 (33.21(0.014)%)	
CVD status, n (%)				< 0.001
No CVD	159,253,860 (91.73(0.003)%)	147,158,677 (92.74(0.003)%)	12,095,183 (81.05(0.010)%)	
CVD	14,349,917 (8.27(0.003)%)	11,521,989 (7.26(0.003)%)	2,827,928 (18.95(0.010)%)	
Sleep duration status, n (%)				< 0.001
Short (< = 7 h)	115,562,454 (66.57(0.005)%)	104,699,284 (65.98(0.005)%)	10,863,170 (72.79(0.014)%)	
Appropriate (7–9 h)	54,334,805 (31.30(0.005)%)	50,672,250 (31.93(0.005)%)	3,662,555 (24.54(0.013)%)	
Long (> 9 h)	3,706,518 (2.13(0.001)%)	3,309,132 (2.09(0.001)%)	397,386 (2.66(0.004)%)	

Note

1 Mean (SE); n (% (SE (%)) %)

2 Wilcoxon rank-sum test for complex survey samples; chi-squared test with Rao & Scott's second-order correction

Abbreviation BMI, Body Mass Index; PIR, poverty index ratio; CVD, cardiovascular disease

Five multivariate logistic regression models were constructed to explore the associations between sedentary behavior and sleep disturbances (Table 3). Participants were stratified by sedentary time into four quartiles: Q1 (<3 h), Q2 (3<=Q2<5 h), Q3 (5<=Q3<8 h), and Q4 (8<=Q4<20 h). The Q1 group, which serves as the reference for statistical analysis, accounted for 33.63% of all participants. The remaining quartiles included Q2 (24.13%), Q3 (25.70%), and Q4 (16.54%). In the unadjusted (crude) model, a significant increasing trend of odds ratios (ORs) for sleep disturbances with higher sedentary time was observed (Q1 as reference: Q2: OR, 1.31; 95% CI, 1.09–1.58; $P=0.005$; Q3: OR, 1.62; 95% CI, 1.39–1.88; $P<0.001$; Q4: OR, 1.75; 95% CI, 1.48–2.06; $P<0.001$; P for trend < 0.001) (Table 3).

The results of the adjusted models were consistent with the crude model (Table 3). Adjusted model 1, which accounted for gender, age, and BMI, demonstrated a positive association between sedentary time and sleep disturbances (Q1 as reference: Q2: OR, 1.23; 95% CI, 1.02–1.49; $P=0.033$; Q3: OR, 1.48; 95% CI, 1.25–1.74; $P<0.001$; Q4: OR, 1.58; 95% CI, 1.32–1.89; $P<0.001$; P for trend < 0.001). Adjusted model 2, with adjustments limited to recreational type, also demonstrated a positive relationship between sedentary time and the odds of sleep disturbances. The odds increased with sedentary time (Q1 as reference: Q2: OR, 1.28; 95% CI, 1.06–1.56; $P=0.011$; Q3: OR, 1.56; 95% CI, 1.34–1.82; $P<0.001$; Q4: OR, 1.72; 95% CI, 1.46–2.02; $P<0.001$). The overall trend was significant (P for trend < 0.001). Adjusted model 3 included additional variables such as PIR type, smoking status, drinking status, and sleep duration type. The ORs using Q1 as the reference category were as follows: Q2 showed an OR of 1.27 [95% CI 1.05–1.54], $P=0.015$; Q3 showed an OR of 1.56 [95% CI 1.33–1.82], $P<0.001$; and Q4 showed an OR of 1.74 [95% CI 1.47–2.05], $P<0.001$. The OR for sleep disturbances increased with increasing sedentary time, indicating a significant trend (P for trend < 0.001). Adjusted model 4 incorporated a broader range of variables, including gender, age, marital type, education type, race, PIR, waist circumference, recreational type, smoking status, drinking status,

Table 2 Stratified analysis based on potential covariates

Variable	Levels	OR (95% CI)				P for trend	P for interaction
		Q1 (0 <= Q1 < 3 h)	Q2 (3 <= Q2 < 5 h)	Q3 (5 <= Q3 < 8 h)	Q4 (8 <= Q4 < 20 h)		
Gender	Male (n = 10,808)	Ref	1.30 (1.01–1.66) *	1.70 (1.37–2.11) ***	1.73 (1.33–2.25) ***	< 0.001	0.837
	Female (n = 10,606)	Ref	1.33 (1.02–1.72) *	1.53 (1.21–1.92) ***	1.76 (1.36–2.27) ***	< 0.001	
Age group	< 45 (n = 9,086)	Ref	1.42 (1.05–1.92) *	1.56 (1.15–2.13) **	1.71 (1.25–2.33) **	< 0.001	0.979
	45–65 (n = 7,357)	Ref	1.20 (0.90–1.62) &	1.58 (1.25-2.00) ***	1.73 (1.34–2.24) ***	< 0.001	
	> 65 (n = 4,971)	Ref	1.25 (0.84–1.86) &	1.56 (1.12–2.16) **	1.71 (1.16–2.51) **	0.001	
Marital	Married/living with partner (n = 12,821)	Ref	1.28 (1.02–1.61) *	1.68 (1.37–2.06) ***	1.72 (1.42–2.08) ***	< 0.001	0.843
	Divorced/separated/widowed (n = 4,773)	Ref	1.52 (1.09–2.13) *	1.74 (1.26–2.42) **	2.01 (1.44–2.81) ***	< 0.001	
	Never married (n = 3,820)	Ref	1.28 (0.77–2.16) &	1.29 (0.80–2.07) &	1.68 (0.99–2.86) &	0.06	
Education	College graduate/above/equal (n = 11,188)	Ref	1.40 (1.09–1.80) *	1.54 (1.24–1.90) ***	1.74(1.39–2.19) ***	< 0.001	0.481
	High school graduated/equal (n = 4,971)	Ref	1.06 (0.74–1.50) &	1.61 (1.20–2.16) **	1.50 (1.03–2.20) *	< 0.001	
	9-11th grade or less (n = 5,255)	Ref	1.45 (1.04–2.03) *	1.99 (1.46–2.70) ***	2.36 (1.62–3.43) ***	< 0.001	
Race	White (n = 10,124)	Ref	1.32 (1.04–1.68) *	1.64 (1.35–1.99) ***	1.7 1(1.39–2.11) ***	< 0.001	0.479
	Black (n = 4,499)	Ref	1.32 (0.96–1.80) &	1.63 (1.22–2.18) **	2.06 (1.49–2.85) ***	< 0.001	
	Mexican American (n = 3,202)	Ref	1.67 (1.12–2.49) *	1.60 (0.97–2.62) &	1.73 (1.03–2.93) *	0.014	
	Other race (n = 3,589)	Ref	0.86 (0.52–1.42) &	1.13 (0.71–1.80) &	1.18 (0.69–2.02) &	0.439	
Family PIR	Low (< 1.0) (n = 4,413)	Ref	1.14 (0.84–1.53) &	1.40 (1.02–1.94) *	2.65 (1.82–3.87) ***	< 0.001	0.043
	Middle (1.0–3.0) (n = 8,835)	Ref	1.29 (0.98–1.70) &	1.72 (1.33–2.24) ***	1.70 (1.26–2.31) ***	< 0.001	
	High (> 3.0) (n = 8,166)	Ref	1.41(1.01–1.97) *	1.63 (1.23–2.16) ***	1.71(1.26–2.31) ***	< 0.001	
BMI	< 25.0 kg/m^2 (n = 6,337)	Ref	1.47 (1.00-2.16) &	1.95 (1.37–2.78) ***	1.83 (1.16–2.90) *	0.002	0.243
	25.0–29.9 kg/m^2 (n = 7,183)	Ref	1.24 (0.86–1.78) &	1.39 (1.01–1.91) *	1.19 (0.85–1.67) &	0.121	
	>= 30 kg/m^2 (n = 7,894)	Ref	1.22 (0.96–1.54) &	1.46 (1.17–1.83) **	1.76 (1.38–2.24) ***	< 0.001	
Waist circumference	Normal (n = 5,285)	Ref	1.14 (0.69–1.89) &	1.64 (1.06–2.54) *	1.36 (0.77–2.38) &	0.091	0.731
	High (n = 16,129)	Ref	1.30 (1.05–1.60) *	1.53 (1.30–1.81) ***	1.72 (1.43–2.07) ***	< 0.001	
Smoke status	Never smoker (n = 11,451)	Ref	1.35 (1.02–1.77) *	1.58 (1.24–2.01) ***	1.38 (1.09–1.75) **	< 0.001	0.014
	Former smoker (n = 5,316)	Ref	1.37 (0.97–1.94) &	1.66 (1.21–2.28) **	2.53 (1.89–3.40) ***	< 0.001	
	Current smoker (n = 4,647)	Ref	1.16 (0.81–1.65) &	1.6 4(1.18–2.29) **	1.64 (1.10–2.44) *	0.002	
Drink status	Never drinker (n = 2,840)	Ref	1.18 (0.65–2.14) &	1.16 (0.79–1.70) &	1.04 (0.63–1.71) &	0.682	0.069
	Former drinker (n = 3,997)	Ref	1.37 (0.93–2.04) &	2.12 (1.52–2.95) ***	2.64 (1.73–4.05) ***	< 0.001	
	Current drinker (n = 14,577)	Ref	1.32 (1.07–1.64) *	1.55 (1.30–1.85) ***	1.71 (1.36–2.14) ***	< 0.001	
Diabetes status	No diabetes (n = 15,831)	Ref	1.30 (1.04–1.64) *	1.55 (1.27–1.89) ***	1.49 (1.21–1.84) ***	< 0.001	0.126
	Diabetes/Prediabetes (n = 5,583)	Ref	1.26 (0.96–1.66) &	1.60 (1.21–2.12) **	2.19 (1.64–2.93) ***	< 0.001	
CVD status	No CVD (n = 19,127)	Ref	1.33 (1.08–1.62) **	1.55 (1.31–1.84) ***	1.83 (1.53–2.19) ***	< 0.001	0.263
	CVD (n = 2,287)	Ref	1.01 (0.64–1.58) &	1.34 (0.91–1.99) &	1.17 (0.78–1.77) &	0.153	
Recreational activities	No activities (n = 10,462)	Ref	1.22 (0.95–1.56) &	1.79 (1.42–2.26) ***	2.00 (1.56–2.56) ***	< 0.001	0.056
	Moderate (n = 5,943)	Ref	1.20 (0.83–1.74) &	1.15 (0.83–1.59) &	1.58 (1.12–2.22) **	0.024	
	Vigorous (n = 5,009)	Ref	1.63 (1.09–2.44) *	1.64 (1.21–2.23) **	1.28 (0.84–1.94) &	0.071	
Sleep duration	Short (<= 7 h) (n = 14,197)	Ref	1.43 (1.17–1.75) ***	1.64 (1.38–1.94) ***	1.75 (1.45–2.12) ***	< 0.001	< 0.001
	Appropriate (7–9 h) (n = 6,661)	Ref	1.12 (0.73–1.71) &	1.73 (1.20–2.49) **	1.70 (1.13–2.57) *	0.001	
	Long (> 9 h) (n = 556)	Ref	0.41 (0.14–1.20) &	0.54 (0.23–1.25) &	1.48 (0.71–3.09) &	0.322	

Note Stratified analysis based on age, sex, marital type, education type, race, PIR, BMI, waist circumference, recreational type, smoking status, drinking status, diabetes history, and heart disease history, sleep duration. Sedentary time quartile cut points: Q1, 0 <= Q1 < 3 h; Q2, 3 <= Q2 < 5 h; Q3, 5 <= Q3 < 8 h; Q4, 8 <= Q4 < 20 h. An interaction was considered significant if the P value was less than 0.1. &: P-value > 0.05; *: P-value < 0.05; **: P-value < 0.01; ***: P-value < 0.001. *Abbreviation* OR, odds ratio; CI, Confidence intervals; Ref, reference; BMI, Body Mass Index; PIR, poverty index ratio; CVD, cardiovascular disease

Table 3 The association between sedentary behavior and sleep disturbances

Characteristic	Crude model [a]		Adjusted model 1 [b]		Adjusted model 2 [c]		Adjusted model 3 [d]		Adjusted model 4 [e]	
	OR (95% CI) [1]	*P*-value	OR (95% CI) [1]	*P*-value	OR (95% CI) [1]	*P*-value	OR (95% CI) [1]	*P*-value	OR (95% CI) [1]	*P*-value
Sedentary behavior group [#]		*P* for trend < 0.001		*P* for trend < 0.001		*P* for trend < 0.001		*P* for trend < 0.001		*P* for trend < 0.001
Q1 (0 <= Q1 < 3 h)	Ref.		Ref.		Ref.		Ref.		Ref.	
Q2 (3 <= Q2 < 5 h)	1.31 (1.09 to 1.58)	0.005	1.23 (1.02 to 1.49)	0.033	1.28 (1.06 to 1.56)	0.011	1.27 (1.05 to 1.54)	0.015	1.18 (0.96 to 1.44)	0.1
Q3 (5 <= Q3 < 8 h)	1.62 (1.39 to 1.88)	< 0.001	1.48 (1.25 to 1.74)	< 0.001	1.56 (1.34 to 1.82)	< 0.001	1.56 (1.33 to 1.82)	< 0.001	1.35 (1.14 to 1.59)	< 0.001
Q4 (8 <= Q4 < 20 h)	1.75 (1.48 to 2.06)	< 0.001	1.58 (1.32 to 1.89)	< 0.001	1.72 (1.46 to 2.02)	< 0.001	1.74 (1.47 to 2.05)	< 0.001	1.45 (1.21 to 1.75)	< 0.001

Note

1 OR = Odds Ratio, CI = Confidence Interval

Sedentary time quartile cut points: Q1, 0 <= Q1 < 3 h; Q2, 3 <= Q2 < 5 h; Q3, 5 <= Q3 < 8 h; Q4, 8 <= Q4 < 20 h

P for trend was calculated using sedentary hours as a continuous variable

a Crude Model: unadjusted

b Adjusted Model 1: adjusted for gender, age type and BMI type

c Adjusted Model 2: adjusted for recreational type

d Adjusted Model 3: adjusted for recreational type, PIR type, smoke status, drink status, sleep type. These covariables were verified by interaction, and *P* for interaction < 0.1

e Adjusted Model 4: adjusted for gender, age, marital type, education type, race, PIR, waist circumference, recreational type, smoke status, drink status, DM status, CVD status, sleep type, BMI

Covariates classification:

Age classification: < 45 years, 45–60 years, > 60 years

PIR classification: Low (< 1.0), Middle (1.0–3.0), High (> 3.0)

Waist circumference classification: Normal (<= 94 for male and <= 80 for female), High: other groups

Education status: 9-11th grade or less group (includes 12th grade with no diploma), high school graduated/equal group, college graduate/above/equal group

Marital status: living with partner and married group, divorced/separated/widowed group, and never married group

Race: White group, Black group, Mexican American group and the other race group

BMI classification: < 25 kg/m^2, 25.0–29.9 kg/m^2, ≥ 30 kg/m^2

Recreational activities: NO activities, Moderate, Vigorous

Smoking status: (Never smoker, Former smoker, and Current smoker)

Alcohol use status: (Never drinker, Former drinker, and Current drinker)

Abbreviation OR, odds ratio; CI, Confidence intervals; Ref, reference; BMI, Body Mass Index; PIR, poverty index ratio; DM, diabetes mellitus; CVD, cardiovascular disease

DM status, CVD status, sleep duration type, and BMI. In this model, the OR for the Q2 subgroup did not significantly differ from the reference group Q1 (Q2: OR, 1.18; 95% CI, 0.96–1.44; *P* = 0.1). However, for the Q3 and Q4 subgroups, the ORs indicated an increased risk of sleep disturbances with longer sedentary time (Q3: OR, 1.35; 95% CI, 1.14–1.59; *P* < 0.001; Q4: OR, 1.45; 95% CI, 1.21–1.75; *P* < 0.001), showing a significant trend (*P* for trend < 0.001).

The unadjusted RCS model revealed a non-linear increase in the risk of sleep disturbances with increasing sedentary time among all participants (*P* for non-linearity < 0.001). For sedentary time > 3 h, the OR was 1.05; 95% CI, 1.03–1.08; *P*-value < 0.001 (Fig. 2A). Subsequently, we conducted stratified analyses to further investigate the associations between sleep disturbances and sedentary time across different levels of recreational activity. In the subgroup of the population reporting no recreational activities, there was a non-linear increase in the risk of sleep disturbances with increasing sedentary time (*P* for non-linearity < 0.001). For sedentary time > 3 h, the OR was 1.07, with a 95% CI of 1.04 to 1.10, and the *P*-value < 0.001 (Fig. 2B). However, no significant non-linear relationship was observed between sleep disturbances and sedentary time in the population with moderate recreational activities; although the OR slightly increased with increasing sedentary time, it was not statistically significant (*P* for non-linearity = 0.612) (Fig. 2C). Similarly, there was no non-linear relationship between sleep disturbances and sedentary time for individuals engaged in vigorous recreational activities (*P* for non-linearity = 0.094) (Fig. 2D).

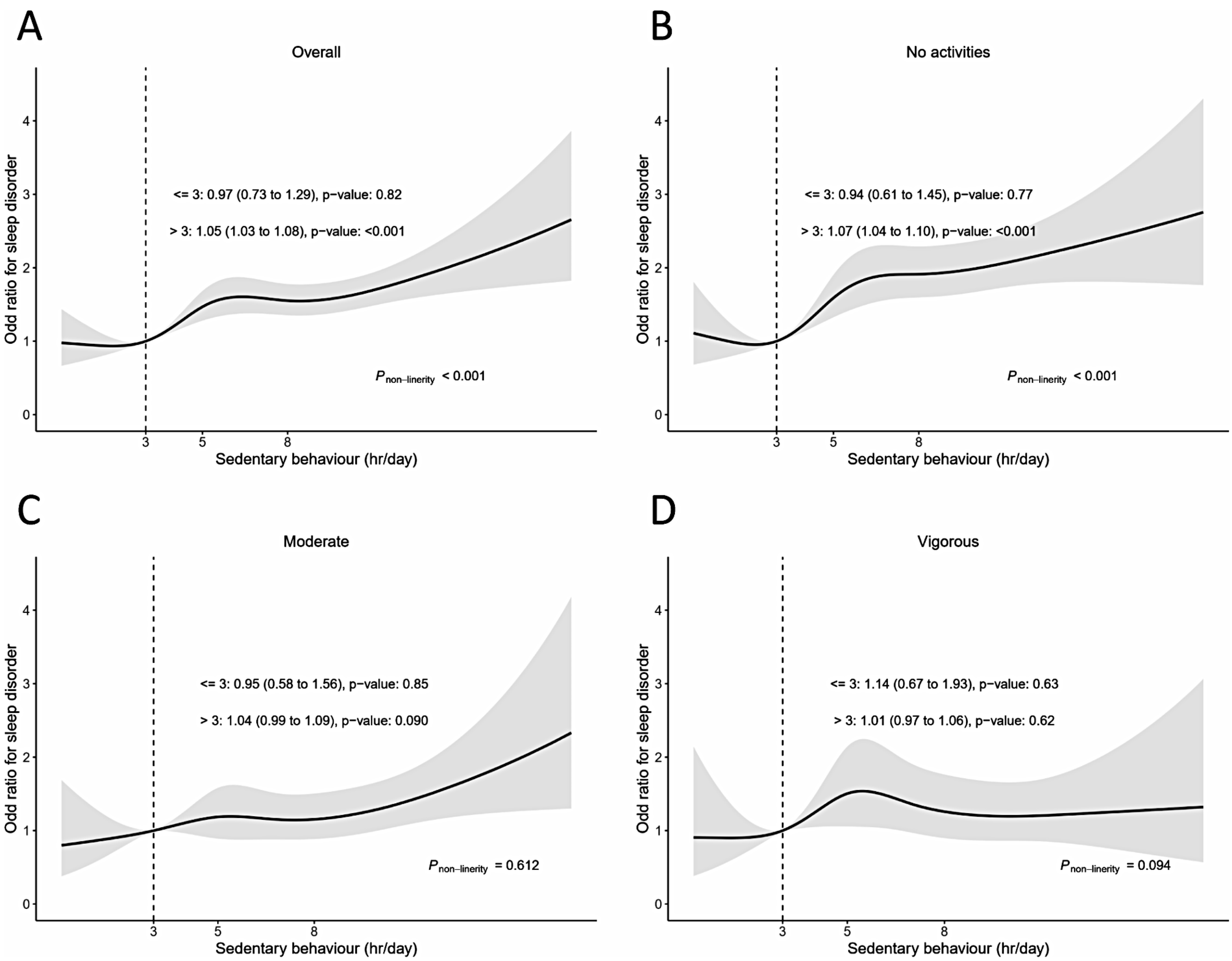

Fig. 2 Association between sedentary behavior and sleep disturbances among overall participants and stratified for recreational type. **A**, Overall participants; **B**, Participants with no recreational activities; **C**, Participants with moderate recreational activities; **D**, Participants with vigorous recreational activities. Estimates no covariates were adjusted

The adjusted RCS model, after adjusting for gender, age group, marital type, education type, race, PRI, waist circumference, smoking status, drinking status, DM status, CVD status, sleep duration type, BMI type, revealed that the risk of sleep disturbances increased non-linearly with increasing sedentary time among all participants (*P* for non-linearity=0.012). For sedentary time>3 h, OR was 1.04, 95% CI, 1.02–1.06, *P*<0.001 (Fig. 3A). Similarly, among the population with no recreational activities, the adjusted RCS model also showed a non-linear increase in the risk of sleep disturbances with increasing sedentary time (*P* for non-linearity=0.005) (Fig. 3B). The non-linearity relationship was not found for participants with moderate recreational activities (*P* for non-linearity=0.565) (Fig. 3C). Interestingly, in the population with vigorous recreational activities, when sedentary time was from 5 to 8 h, the risk no longer increased with additional sedentary time (*P* for non-linearity=0.162) (Fig. 3D).

Discussion

This study was the first to explore the relationship between sedentary behavior and sleep disturbances among participants nationwide who had been diagnosed with sleep disorders by their doctors. The main finding was that sedentary time was a risk factor for sleep disturbances, with the risk increasing as sedentary time increased among all participants. The multivariable logistics regression results showed that the OR for sleep disturbances increased with increasing sedentary time, *P* for trend<0.001. Both the unadjusted and adjusted RCS models revealed a non-linear increase in the risk of sleep disturbances with increasing sedentary time for all participants. In the population with sedentary time more than 5 h per day, the moderate to vigorous recreational activities may weaken the positive correlation between sleep disturbances and sedentary time.

Currently,, a large body of research has shown that sedentary behavior is one of the more serious risk factors for

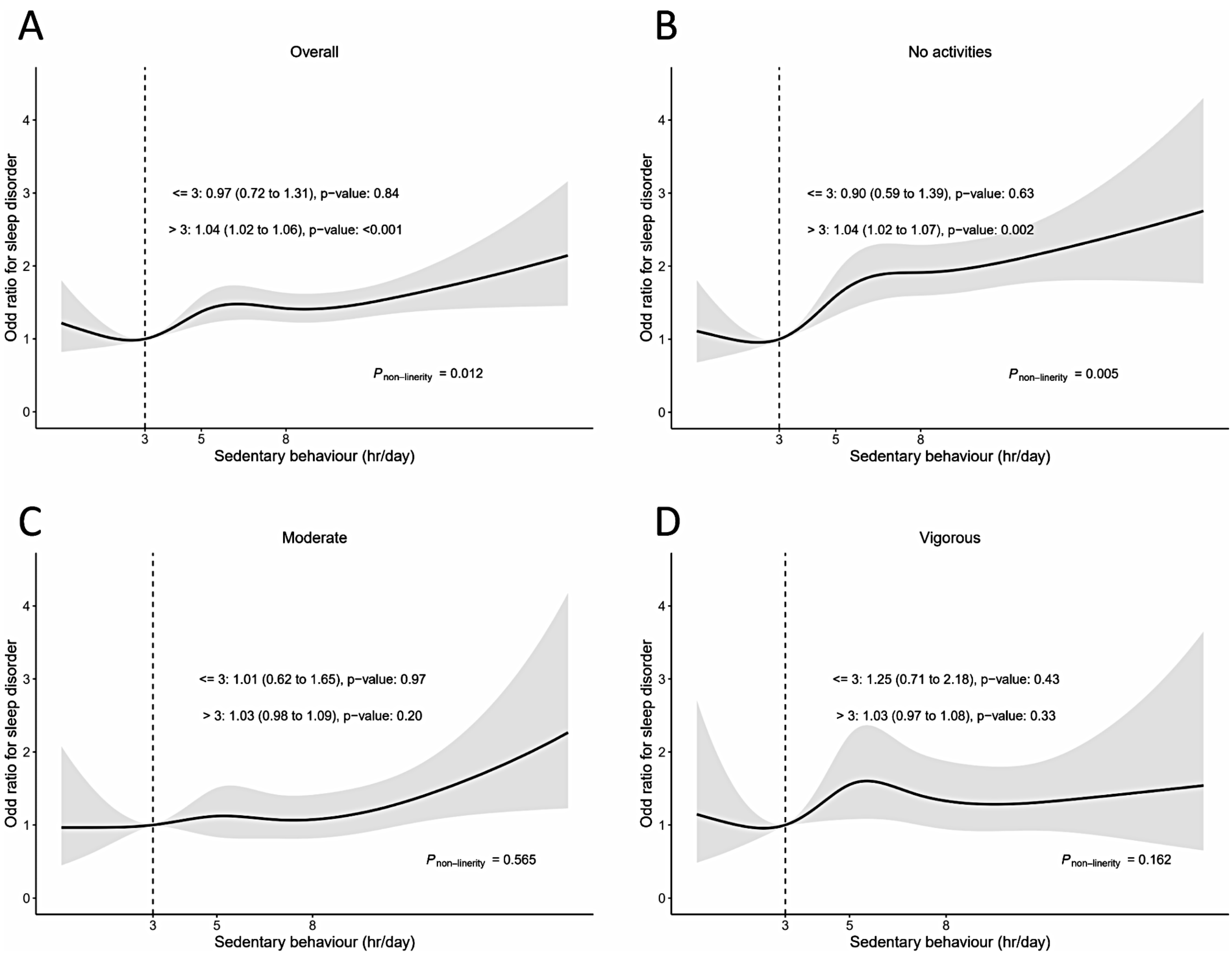

Fig. 3 Association between sedentary behavior and sleep disturbances among overall participants and stratified for recreational type. **A**, Overall participants; **B**, Participants with no recreational activities; **C**, Participants with moderate recreational activities; **D**, Participants with vigorous recreational activities. Estimates adjusted for gender, age group, marital type, education type, race, PRI, waist circumference, smoke status, drink status, DM status, CVD status, sleep duration type, BMI group

health. In several observational studies, television watching and use of computer were often used as proxy for total leisure sedentary behavior [25, 26]. In present study, the sedentary behavior data from NHANES was assessed by the question "How much time do you usually spend sitting on a typical day?", which included the time of sitting at a desk, traveling in a car or bus, reading, playing cards, watching TV or videos, or using a computer, not included time spent sleeping [10]. The estimated prevalence of sedentary time increased among all age groups, which included 10,359 children, 9,639 adolescents, and 31,898 adults from NHANES data 2001–2016, in US population [1]. The literatures also reported that adult population spend an increased amount of sedentary time in Australia and parts of Europe [27–29].

The positive association between sedentary behavior and sleep disturbances was demonstrated in our study, the OR for sleep disturbances increased with increasing sedentary time, which was consistent with previous findings [10, 11, 30–32]. Yanwei You, et al. also suggested that sedentary behavior was a risk factor for sleep disturbances, although based on the participants whose sleep disorders were assessed by the NHANES questionnaire "Have you ever told a doctor or other health professional that you have trouble sleeping?" [10]. Compared to their population, the sleep disturbancess of our subjects were assessed by doctors or other professional, which will be helpful to explore the authenticity and objectivity of the relationship between sedentary behavior and sleep disorders. Another similar study reported that sedentary behavior ≥ 9 hours a day significantly increased the risk of poor sleep quality for subjects [33].

However, the potential mechanisms for explaining the relationship between sedentary behavior and sleep disturbances were not well understood. Several mechanisms have been proposed to explain this correlation [34, 35]. Low sunlight exposure may mediate the association between sedentary behavior and sleep disorders. Sunlight exposure is one of the most important external synchronizer for regulating the sleep-wake cycle [36]. And the daytime sunlight source has a significant impact on the circadian rhythm, which is crucial for a good night's sleep [37]. Moreover, sunlight regulates sleep by driving vitamin D synthesis [38]. For example, the Rotating shift workers with vitamin D deficiency are more likely to have obstructive sleep apnea [39]. Luiz Antonio Alves de Menezes-Junior and colleague reported that vitamin D deficiency was associated with poor sleep quality in sun-insufficient Brazilian adults, and that increasing vitamin D levels could reduce the chance of poor sleep quality. Vitamin D was not associated with poor sleep quality in individuals with sufficient sunlight. The odds of poor sleep quality decrease by 4.2% for each 1 ng/mL increase in vitamin D level [40].

Another aspect, the work environment and occupation type are directly related to sedentary behavior, which is one of the significant social factors that may indirectly affect sleep disturbances. The decline in PA over the years has increased in sedentary occupations and the possibility of working from home [41]. Participants that were working from home during social distancing showed increased odds of screen time and sitting time greater than 8 h/day [42]. Based on national data from Korea, Joo Hye Sung et al. suggested that occupation significantly influences people's activities, with white-collar workers having the longest sedentary times [43].

In contrast to sedentary behavior, the strong evidence from review of 21 randomized controlled trials demonstrated that PA, as effective strategies to improve sleep, positively affected sleep quality, sleep efficiency, and total sleep time in almost all populations [21]. Consistent with this, Christopher E. Kline et al. also mentioned that both acute bouts of PA and regular PA improved sleep outcomes [22]. Excitingly, we also detected the mitigation role of vigorous recreational activities on sleep disorders, although not for total participants only among the participants with sedentary time > 5 h.

The research evidence confirmed that regular exercise and PA had a variety of health benefits for many chronic diseases, including cardiovascular disease, stroke, diabetes, osteoporosis, and obesity, mental health, reduction in mortality, and beneficial effects on sleep quality [44]. A study has reported that the excess risk associated with prolonged sitting can be eliminated for participants with high levels of PA [45]. In particular, it is greatly needed for us to better understand how PA play the role of improving sleep. This requires larger sample sizes, a wider variety of modes, and patterns of PA and sedentary behavior, and more accurate evaluation of sleep outcomes.

Importantly, for the first time, reducing sedentary behavior as part of a global strategy for chronic disease prevention and control, which come from the Global Physical Activity Action Plan (2018–2030), in 2018 [46]. After a short time, the second edition of Physical Activity Guidelines for Americans published in November 2018, which further providing specific recommendations to reduce sedentary behaviors for reducing risk of disease [47].

There were several limitations to consider in this study. Firstly, sedentary time using other devices such as phones and tablets were not captured. This could potentially impact the overall accuracy of the findings, as these devices are commonly used for work, entertainment, and communication. Secondly, this study only analyzed the independent effects of sedentary behavior on sleep disturbances. In this study, we solely examined the association between sedentary behavior and the risk of sleep disorders, without delving into the underlying mechanism or pathway through which sedentary behavior impacts sleep disorders. This is a proposition that we need to further explore in the future. Thirdly, in this study, we only collected a part of the participants' demographic and lifestyle variables, and adjusted them in the statistical analysis. In fact, there may be confounding factors that have a significant impact on sleep disorders that we have not paid attention to, such as mental health conditions or medication use, which may lead to biased conclusions in the analysis. Furthermore, this study lacked information of different sleep disorders such as insomnia, sleep apnea, restless leg syndrome, and narcolepsy. Without this specific data, it is difficult to fully understand the impact of sedentary behavior on these individual sleep disorders. Further research that includes detailed information on the types of sleep disorders experienced by participants would provide a more comprehensive understanding of effects of sedentary behavior on various sleep outcomes. Finally, the samples in this study mainly come from a sample survey, and the results was taken as general evidence of the sampled population. They only reflect the relationship between sedentary behavior and sleep disorders in the sampled population. In future, we need to analyze the detail reasons and possible mechanisms of the positive relationship between sleep disorders and sedentary behavior to explore effective preventive intervention strategies.

Conclusion

In this nationally representative survey of the US population from 2005 to 2014, time spent in sedentary behaviors was positively associated with sleep disturbances among all participants. Moreover, we detected the mitigation role of vigorous recreational activities on sleep disturbances, among the participants with sedentary time more than 5 h. To some extent, vigorous recreational activities may mitigate the additional risk of sleep disorders associated with sedentary behaviors.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20114-7.

Supplementary Material 1

Supplementary Material 2

Author contributions

Study conception and design: Jiasi Wang and Shilin Li. Data collection and analysis: Jiasi Wang and Liangli Sun. Interpretation of results: Jiasi Wang and Shilin Li. Drafting of the manuscript: Shilin Li and Huaying Liu. Providing valuable insight regarding the approach and organization of the manuscript: Tingting Wang and Jie Zhang. All authors reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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Data availability

Publicly available datasets were analyzed in this study. These data can be found at the following URL: https://www.cdc.gov/nchs/nhanes/. The R code of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval

The ethical approval of NHANES was granted by the US National Center for Health Statistics Research Ethics Review Board (Protocol No. 98 – 12, Protocol No. 2011-17, Continuation of Protocol No. 2011-17, Protocol No. 2018-01) (available at: https://www.cdc.gov/nchs/nhanes/irba98.htm). The NHANES is a publicly available dataset. The analysis in this study is a secondary analysis of NHANES data; thus, ethical approval is exempted under the US Health and Human Services (HHS) regulations at 45 CFR 46.104 (available at: https://www.hhs.gov/ohrp/regulations-and-policy/regulations/45-cfr-46/common-rule-subpart-a-46104/index.html). Written informed consent was acquired before household interview and health examinations; the participants were assured that the data collected will be used only for stated purposes and will not be disclosed or released to others without the consent (available at: https://www.cdc.gov/nchs/nhanes/genetics/genetic_participants.htm).

Competing interests

The authors declare no competing interests.

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