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ORIGINAL RESEARCH

Association Between Physical Activity, Sedentary Behavior and Sleep Disorders in Chronic Obstructive Pulmonary Disease Patients: A Cross-Sectional Study

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Objective: Sleep disorder is a common comorbidity in chronic obstructive pulmonary disease (COPD). We aim to explore the potential association between daily sitting time (DST), leisure-time physical activity (LTPA) and sleep disorders in COPD patients.

Methods: The sleep, LTPA, and DST data of participants with COPD were extracted from the National Health and Nutrition Examination Survey (NHANES) portal (2007–2012), basing on Global Physical Activity Questionnaire. The *t*-test, Mann–Whitney test, or chi-square test were employed to analyze the differences between two groups. The weighted binomial logistic regression model was used to estimate the odds ratio (OR) and 95% confidence interval (CI) of DST and LTPA on sleep disorders. The analyses were conducted from April 1 to July 1, 2023.

Results: A total of 2063 COPD samples were included in this work, of which 58% had LTPA < 150 min/wk and 48% had DST > 6h. Patients with sleep disorders had longer sedentary time (DST > 6h: 151, DST > 8h: 105) and less physical activity (LTPA < 150min/wk: 185). Longer sedentary time was correlated with a higher risk of sleep disorders, while LTPA showed no significant correlation with sleep disorders. The conjoint analysis revealed that the risk of sleep disorders in patients with LTPA <150 min/wk and DST > 8h was 5.88 times (95% CI: 1.80–19.2) great than that of patients with LTPA≥150 min/wk and DST < 4h.

Conclusion: COPD patients often lacked physical activity and exhibited sedentary behaviors. Long-term sedentary behavior was associated with elevated risk of sleep disorders in COPD patients. More light intensity physical activity and supervised exercise programs are probably good choices to prevent sleep disorders in COPD population.

Keywords: chronic obstructive pulmonary disease, COPD, sleep disorders, physical activity, sedentary behavior, National Health and Nutrition Examination Survey, NHANES

Introduction

Chronic obstructive pulmonary disease (COPD), characterized by persistent airflow obstruction caused by structural changes in airways or alveoli, is a prominent cause of disability and mortality worldwide.[1] More recently, it has been indicated that the prevalence of COPD has reached about 10% around world and about 8.5% in China.[2,3] In China, it is the most common respiratory disease, affecting a staggering 99 million individuals.[3] This ailment exhibits a high degree of heterogeneity and often accompanies various comorbidities and complications.[1,4] Of which, sleep disorder is one of the most prevalent comorbidities in patients with COPD, closely associating with adverse outcomes, such as death and acute exacerbations.[5]

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Sleep exerts a crucial role in the maintenance of health due to occupying one-third of human life.[6] Typically, in COPD population, obstructive sleep apnea (OSA) and insomnia and restless leg syndrome (RLS) are considered two common subtypes of sleep disorders.[7] It has been indicated that both OSA and insomnia could contribute to an increased susceptibility to acute exacerbation of COPD (AECOPD).[8] It follows that there is probably a bidirectional relationship between sleep quality and prognosis of COPD patients. The clinical symptoms of COPD, like mucus plugs, lower oxygen saturation,etc., would lead to a poorer sleep quality. On the other hand, sleep disturbance could accentuate the impaired immune function, systemic inflammation, and physical inactivity of COPD patients, thereby leading to undesired outcomes.[6,8] However, more detailed information between sleep disorders in patients with COPD are still not fully clarified at present, which poses an essential challenge for the clinical work. Moreover, despite the significant impacts of sleep disorders on COPD patients, current treatment protocols for the disease often fail to address sleep disorder intervention techniques.[9] Therefore, it is imperative to identify realistic techniques to address sleep disorders in COPD patients.

Physical activity has been currently regarded as a pivotal factor influencing the well-being of COPD patients.[10] Whereas, the exercise tolerability of COPD patients is largely limited by lung function impairments, physical capacity decline, and comorbidities like coronary heart disease and sarcopenia, which thereby leads to exertional dyspnea and physical activity avoidance.[11,12] Moreover, the evasion reflex of some patients might be counterbalanced temporarily, while it is more challenging to solve their long-term training adherence and self-consciousness in the daily life.[13,14] A decrease in physical activity can significantly increase the risk of hospital readmission, acute exacerbation, and mortality among COPD patients, and can also be linked to a diminished quality of life.[15,16] Conversely, COPD patients with regular physical activity tend to experience improvements in dyspnea symptoms, physical fitness, and exercise tolerance.[17] Moreover, numerous studies have demonstrated the beneficial impacts of physical activity on sleep quality.[18,19] Whereas sedentary behavior has been linked to various health concerns,[20] including a heightened risk of insomnia and sleep disorders.[21,22] It has been reported that reducing sedentary behavior and engaging in regular physical activity are effective strategies to enhance sleep quality.[23] Thus, augmenting physical activity and minimizing sedentary behavior may present valuable non-pharmacological strategies for COPD patients seeking to improve their sleep quality, ultimately contributing to their overall health and well-being. However, there is limited evidence to support this therapeutic technique. Leisure physical activity time (LTPA) and daily sitting time (DST) are two important indexes for evaluating physical activity in many human diseases.[24] Hence, the predominant purpose herein is to explore the conjoint impacts of LTPA and DST on sleep disorders in COPD patients, thereby to provide more reference information for the better clinical treatment strategy of COPD.

In this present work, we aim to deeply explore the association of sleep disorders with leisure physical activity time (LTPA) and sedentary time among COPD patients, via data in National Health and Nutrition Examination Survey (NHANES) database. We hypothesize that longer sedentary time might increase the risk of sleep disorders in COPD population. Our findings are promising in providing more clinical insights into developing novel intervention measures for COPD patients with sleep disorders. Meanwhile, our data are expected to provide more solid evidence for advising proper physical activity among COPD patients, as well as to call for the specific attention to sleep quality in COPD patients.

Materials and Methods

Data Sources and Participants

The NHANES was a comprehensive, population-based cross-sectional survey that encompassed health and nutrition information of the household population of the United States. A total of three cycles (2007–2012 years) of NHANES data released by the Centers for Disease Control and Prevention (CDC) were downloaded in this study. The demographic data of disease classifications, lung function measures, disease information, and questionnaire data were collected and merged. From 2007 to 2012, a total of 30,442 participants were successfully randomized into the trial. We included individuals with age ≥ 40 years who possessed lung function fulfilling the diagnostic criteria for COPD, chronic bronchitis, or emphysema (N = 2083). Considering the date integrity and analytical accuracy, we excluded participants with missing data on sleep (n = 9), physical activity (n = 0), and sedentary time (n = 11). As the missing data of these key information would adversely affect the evaluation accuracy, potential data bias, and the robustness of statistical analyses (missing data <5%). All data used in this study were publicly available and demographic-weighted for subsequent analysis (https://www.cdc.gov/nchs/nhanes/). In addition, our study was exempt from approval from the ethic committee of Dongying People's Hospital, as the data in NHANES database was publicly accessible to all researchers.

Study Variables

Ascertainment of COPD

Spirometry was conducted on subjects who fulfilled inclusion criteria during 2007–2012. As most participants did not have post-bronchodilator spirometry, pre-bronchodilator forced expiratory volume in 1 second (FEV1)/forced volume vital capacity (FVC) <0.7 was used to identify COPD. The FEV1 (variable name: SPXNFEV1) and FVC (variable name: SPXNFVC) data were obtained from the "Spirometry-Pre and Post-Bronchodilator" of Examination Data in NHANES portal. This definition was referred to the GOLD criteria for COPD diagnosis and staging, which was also in line with the 2004 American Thoracic Society (ATS)/European Respiratory Society (ERS) criteria.[25] Moreover, in family interviews, participants were asked to complete two questions about emphysema or chronic bronchitis: "Has a doctor ever told you that you have emphysema?" and "Has a doctor ever told you that you have chronic bronchitis?" If "yes", they were considered to have COPD. The above data could be found in Medical Conditions of Questionnaire Data in NHANES portal.

Ascertainment of Sleep Disorders

Regarding the definition of sleep disorders, it was performed referring to the previous studies.[26,27] Basing on the Sleep Disorders related Questionnaire Data in NHANES portal (https://wwwn.cdc.gov/Nchs/Nhanes/2007-2008/SLQ_E.htm), participants were asked to complete two questions: "(Have you/Has SP) ever told a doctor or other health professional that (you have/s/he has) trouble sleeping?" or "(Have you/Has SP) ever been told by a doctor or other health professional that (you have/s/he has) a sleep disorder?". If the answer was "yes", they were considered to have sleep disorders. The Questionnaire was conducted in the home, by trained interviewers, using the Computer-Assisted Personal Interview (CAPI) system.

Ascertainment of Leisure Time Physical Activity (LTPA) and Daily Sitting Time (DST)

LTPA and DST related data were obtained from the Physical Activity related Questionnaire Data in NHANES portal (https://wwwn.cdc.gov/Nchs/Data/Nhanes/Public/2007/DataFiles/PAQ_E.htm). The General Practice Assessment Questionnaire (GPAQ) (a validated, suitable and acceptable instrument[28]) was used to investigate the Leisure Time Physical Activity (LTPA) and Daily Sitting Time (DST) of participants. GPAQ was a previously validated questionnaire developed by WHO for monitoring physical activity. It had been utilized in over 100 countries worldwide through the WHO's step-by-step monitoring method.

The LTPA data were obtained via a staff-administered questionnaire,[29] which included the following physical activities included martial arts, gymnastics, dance, acrobatics, jogging, swimming, playing soccer, basketball or tennis, and playing badminton, volleyball, or table tennis.[30] In the interview, participants offered their moderate and high-intensity entertainment activities during a typical week.[31] The duration of LTPA was defined as the minutes of moderate-intensity activities plus twice the minutes of high-intensity activities (variable names: PAQ650, PAQ655, PAD660, PAQ665, PAQ670, PAD675). Then, based on the 2018 Physical Activity Guidelines for Americans, participants were divided into three categories: inactive (non-physical activity), insufficient activity (0 time<150 min/wk), and sufficient activity (activity time≥150 min/wk).[32]

DST was evaluated based on the answer "On a typical day, how much time do you usually spend sitting at school, at home, getting to and from places, or with friends, including time spent sitting at a desk, traveling in a car or bus, reading, playing cards, watching television, or using a computer? (variable name: PAD680). (the data were collected from the Physical Activity related Questionnaire, https://wwwn.cdc.gov/Nchs/Data/Nhanes/Public/2007/DataFiles/PAQ_E.htm)".

The participants were divided into four groups based on DST (h/d), 0–4 h/d, 4–6 h/d, 6–8 h/d, and ≥ 8 h/d (referring to previous studies).[33]

Covariates

To comprehensively evaluate the multifaceted relationship between LTPA, DST and sleep disorder in COPD patients, we have searched plenty of literature and following covariates were included.[34–36] Age exerted a vital role as an essential covariate, contributing to a thorough understanding of the potential influence that advancing years may exert on sleep quality. Gender was a crucial demographic characteristic of the participant, which might influence the physical activity and sleep quality. Considering the cultural and genetic variations, the ethnicity was also included to capture the potential nuances and heterogeneity relating to this covariate.

Body measurements are necessary factors for evaluating healthy status. As for lifestyle factors, smoking and drinking history were both important factors contributing to the development of COPD. Regarding comorbidities of participants, these problems often jointly influenced the physical activity, sleep quality, and progression of COPD, via a complex integrated way.

To assess the influence of above potential confounding factors, the detailed grouping status were summarized, including age (40–60 years and 60–80 years), gender, race/ethnicity (Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, and Other Race), body mass index (BMI, defined as weight (kg)/height (m^2)) (<25, 25–30, ≥30 kg/m^2). Smoking status (never, former, current), drinking status (more than 10 drinks/month, 5–10 drinks/month, 1–5 drinks/month, non-drinker), and comorbidity index (1, 2, ≥3) calculated by the complications or coexisting diseases, including asthma, congestive heart failure, coronary heart disease, diabetes, hypertension, tumor, and arthritis, based on the participants' self-report.

Statistical Analysis

To ensure the reliability of the results in our study, we followed the National Center for Health Statistics (NCHS) guidelines for opinion selection weights. Several sample weights such as interview weight (wtint2yr), Mobile Examination Center (MEC), exam weight (wtmec2yr), and many sub-sample weights were derived from the NHANES database. Using the suitable sample weights, we combined data from three cycles including 2007–2008, 2009–2010, and 2011–2012 based on unique respondent serial numbers. All analyses took into weights, strata, and cluster design variables to explain the complex complexity of the NCHS-directed NHANES.

Continuous variables were presented as the mean ± standard deviation (SD), while categorical variables were reported as the number and percentage of subjects. The t-tests, Mann–Whitney tests, and chi-square tests were used to assess the differences between two groups. The weighted binomial logistic regression model was used to estimate the odds ratio (OR) and 95% confidence interval (CI) of LTPA and DST and sleep disorders, respectively. The confounding factors including age, gender, race, BMI, smoking status, alcohol consumption status, and comorbidity index were adjusted in the model. Additionally, subgroup analysis was carried out based on age, gender, and BMI.

To investigate the joint association, participants were classified based on their DST and LTPA. Then, the regression model was adjusted for the same set of covariates to evaluate the relationship with sleep disorders. Finally, considering that lung function parameters were an important confounding factor, we excluded the samples with missing lung function parameters and further analyzed the relationship between LTPA and sleep disorders in the COPD samples.

All statistical analyses were performed using R (Version: 4.2.0) (http://www.r-project.org), and $p < 0.05$ was considered statistically significant.

Results

Population Characteristics

According to the exclusion criteria, a total of 2063 COPD samples (weighted population: 26,734,895) were included (Figure 1). The average age of them was (60.00±11.00) years. Among them, 265 patients (13%) had sleep disorders, 1217 patients (56%) were male, 1346 patients (58%) reported having LTPA of less than 150 min/wk, and the DAT of 921 patients (48%) were more than 6h (Table 1). Furthermore, between patients with and without sleep disorders, we

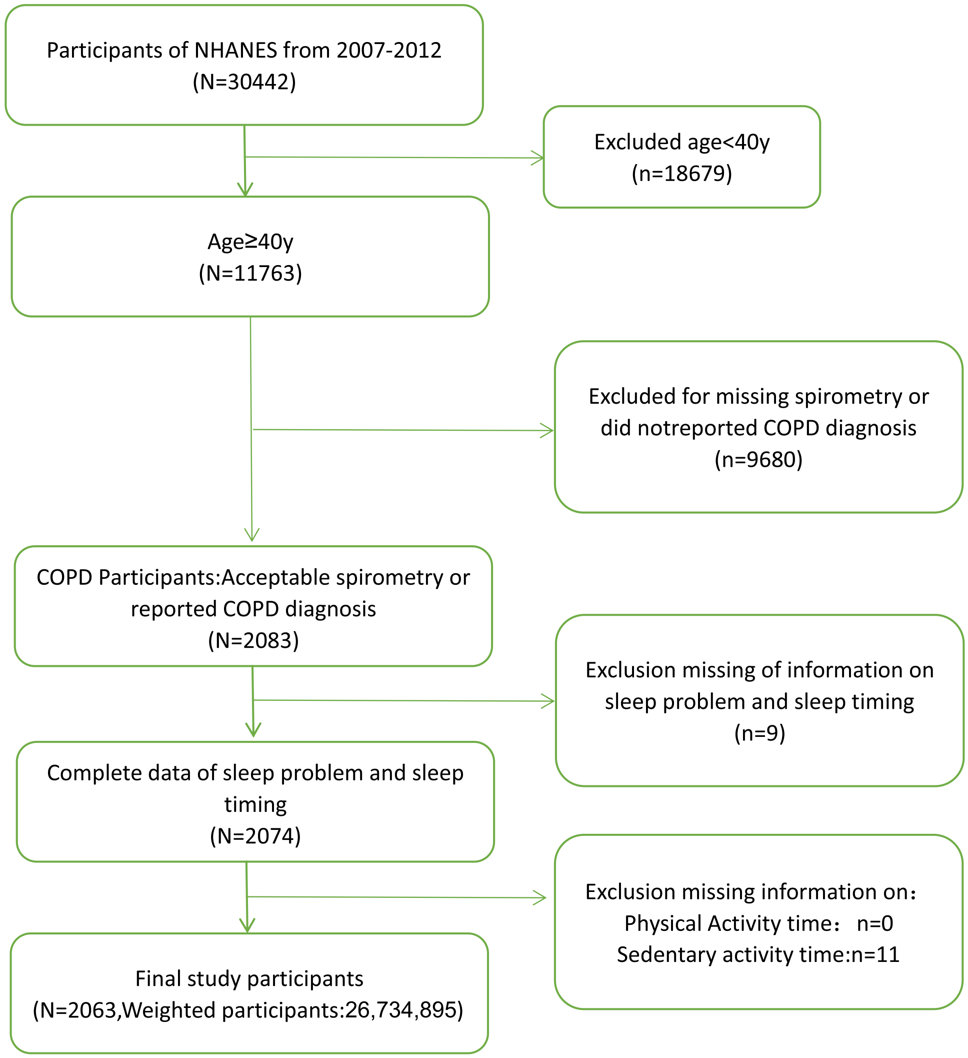

Figure 1 Flowchart of the participants selection from NHANES 2007–2012.

observed significant variations in BMI ($p < 0.001$), comorbidity index ($p < 0.001$), LPTA ($p = 0.017$), and DST ($p < 0.001$). Notably, individuals with sleep disorders spent more time sitting down (DST > 6h: 60%) and less time engaging in recreational physical activity (LTPA < 150 min/wk: 65%). However, for sex, age, race, smoking history, and drinking history, there was no significant difference between the two groups ($p > 0.05$) (Table 1). In addition, we discovered that 65% of patients with sleep disorders had not engaged in any physical activity during a week, whereas only 19% of the patients had engaged in physical activity (LTPA≥150 min/wk) (Table S1).

Association Analyses of LTPA and DST with Sleep Disorders in COPD Patients

To explore the relationship between LTPA, DST, and sleep disorders in COPD patients, we conducted a binomial logistic regression model. The results revealed that compared to DST < 4 hours, prolonged DST was associated with increased risk of sleep disorders (model 1: 4<6h: OR = 2.03, 95% CI: 1.19–3.47; 6<DS6 < DST OR = 2.27, 95% CI: 1.23–4.21; DST> 8h: OR = 2.72, 95% CI: 1.67–4.44, $p < 0.001$), and this association persisted after we adjusted for sex, age, BMI, comorbidity index, smoking and alcohol (model 2–4). In addition, for LTPA, sufficient physical activity was significantly associated with reduced sleep disorders (model 1: OR = 0.56, 95% CI: 0.36–0.87, p=0.012; model 2: OR=0.62, 95% CI: 0.41-0.095, $p = 0.032$) compared to those inactive participants, but the significance disappeared after further adjustment

Table 1 Characteristics of Participants Classified by Sleep Disorders

Characteristic	Overall, N = 26,734,895[a]	No Sleep Disorder, N = 1798 (87%)[a]	Sleep Disorder, N = 265 (13%)[a]	p-value[b]
Sex				>0.9
Female	846 (44%)	729 (44%)	117 (44%)	
Male	1,217 (56%)	1,069 (56%)	148 (56%)	
Age (year)	60.00 ±11.00	60.00 ±11.00	59.00 ±11.00	0.3
Age.group				>0.9
40–60 years	818 (51%)	698 (51%)	120 (51%)	
60–80 years	1,245 (49%)	1,100 (49%)	145 (49%)	
Race				0.8
Mexican American	146 (2.2%)	128 (2.3%)	18 (1.9%)	
Other Hispanic	146 (2.2%)	127 (2.2%)	19 (2.2%)	
Non-Hispanic White	1,238 (83%)	1,078 (83%)	160 (83%)	
Non-Hispanic Black	423 (8.3%)	367 (8.2%)	56 (9.4%)	
Other Race	110 (4.6%)	98 (4.7%)	12 (3.8%)	
BMI (kg/m^2)	28.00 ±6.00	28.00 ±6.00	32.00 ±8.00	<0.001
BMI.group				<0.001
<25	656 (33%)	611 (35%)	45 (19%)	
25 to <30	695 (35%)	624 (37%)	71 (27%)	
30 or greater	666 (32%)	524 (29%)	142 (53%)	
Smoking				0.7
Current smoker	710 (35%)	620 (35%)	90 (32%)	
Former smoker	806 (38%)	692 (38%)	114 (41%)	
Never smoker	547 (27%)	486 (27%)	61 (27%)	
Alcohol				0.3
1–5 drinks/month	932 (47%)	798 (47%)	134 (53%)	
10+ drinks/month	410 (27%)	379 (28%)	31 (19%)	
5–10 drinks/month	131 (8.2%)	117 (8.3%)	14 (7.9%)	
Non-drinker	423 (18%)	361 (17%)	62 (20%)	
Comorbidity index				<0.001
1	543 (29%)	490 (30%)	53 (25%)	
2	404 (23%)	388 (25%)	16 (7.7%)	
3 or greater	1,116 (48%)	920 (45%)	196 (67%)	
LTPA (min/wk)	0 (0, 180)	0 (0, 180)	0 (0, 90)	0.017
LTPA.group				0.039
Inactive	1,346 (58%)	1,161 (57%)	185 (65%)	
Insufficient	264 (15%)	231 (15%)	33 (16%)	
Sufficient	453 (27%)	406 (29%)	47 (19%)	
DST (h)	5.0 (3.0, 8.0)	5.0 (3.0, 8.0)	6.0 (4.0, 10.0)	<0.001
DST.group				0.007
~4	611 (27%)	563 (29%)	48 (15%)	
4~6	531 (25%)	465 (25%)	66 (25%)	
6~8	333 (15%)	287 (15%)	46 (17%)	
8	588 (33%)	483 (31%)	105 (43%)	

Note: [a]n (unweighted) (%); Median (IQR); [b]chi-squared test with Rao & Scott's second-order correction; Wilcoxon rank-sum test for complex survey samples.

for covariates including comorbidity index (model 3: p = 0.055) and smoking/ drinking status (model 4: p=0.071) (Table 2).

Going further, considering the crucial impacts of key factors, we performed subgroup analyses by age (40–60 or 60–80 years), sex (male or female), and BMI (<25, 25–30, or ≥30 kg/m^2). Age has been indicated as an important risk factor for COPD, and there were often different physiological status and lifestyles among various age groups.[37] Gender has been an

Table 2 Association of Daily Sitting Time (DST) and Leisure-Time Physical Activity (LTPA) with Sleep Disorders of COPD Population

Sleep Disorder	Event N (Weighted)	OR (95% CI)			
		Model 1	Model 2	Model 3	Model 4
LTPA, min/wk					
Inactive	2,305,483	—	—	—	—
Insufficient	566,871	0.96(0.57, 1.61)	1.01(0.59, 1.72)	1.02(0.59, 1.78)	0.98(0.50, 1.94)
Sufficient	661,175	0.56(0.36, 0.87)	0.62(0.41, 0.95)	0.66(0.44, 0.98)	0.65(0.42, 1.00)
***P* for tend**	—	0.012	0.032	0.055	0.071
Daily sitting time, h					
~4	513,988	—	—		
4~6	901,507	2.03(1.19, 3.47)	1.90 (1.10, 3.27)	1.87(1.08, 3.24)	1.85(1.04, 3.30)
6~8	605,509	2.27(1.23, 4.21)	2.11 (1.15, 3.87)	1.98(1.07, 3.66)	1.93(1.01, 3.66)
8	1,512,524	2.72(1.67, 4.44)	2.39 (1.42, 4.02)	2.24(1.34, 3.75)	2.11(1.23, 3.63)
***P* for tend**	—	<0.001	0.005	0.010	0.022

Notes: Model 1: Adjusted for age.group; Model 2: Multivariable model adjusted for sex, race, BMI, age; Model 3: Multivariable model adjusted for sex, race, BMI, age, comorbidity index; Model 4: Multivariable model adjusted for sex, race, BMI, age, comorbidity index, smoking, alcohol.
Abbreviations: OR, Odds Ratio; CI, Confidence Interval.

essential factor in the risk and pathogenesis of CODP, which might also influence the physical activity.[38] As for BMI, it was a crucial index to evaluate health status, and it exhibited complex interactions with physical activity, sleep quality, and various human diseases. Then, the age-based subgroup analysis showed that sleep disorders were associated with DST in patients with COPD aged 40–60 years, but not in patients with COPD aged 60–80 years (Table S2). The sex subgroup analysis revealed that the association between sleep disorders and DST was more apparent in men (Table S3). The BMI subgroup analysis showed that sleep disorders was linked to DST when BMI ≥ 30 kg/m2 (Table S4). In the subgroup analysis of LTPA, we discovered that sleep disorders in COPD patients was not associated with DST (Table S5).

Conjoint Analyses of the Association of LTPA and DST with Sleep Disorders in COPD Patients

To explore the conjoint effect of LTPA and DST on sleep disorders in COPD patients, we performed a conjoint analysis with LTPA≥150 min/wk and DST < 4h as the baseline (referred to previous study).[24] The results showed that, for model 1, model 2, model 3, and model 4, the risk of sleep disorders in COPD patients with LTPA <150 min/wk and DST > 8h was 9.75 (95% CI: 2.93–32.52), 7.44 (95% CI: 2.23–24.8), 6.50 (95% CI: 1.93–21.8), and 5.88 times (95% CI: 1.80–19.2) than that of LTPA≥150 min/wk and DST < 4h, respectively. The risk of sleep disorders in COPD patients with LTPA <150 min/wk and DST > 4h was 8.36 (95% CI: 2.47–28.4), 5.79 (95% CI: 1.72–19.5), 5.79 (95% CI: 1.72–19.5), and 5.37 times (95% CI: 1.62–17.8) that of patients with LTPA≥150 min/wk and DST < 4h, respectively. Notably, the risk of sleep disorders increased along with the longer DST (Table 3).

Association of LTPA and DST with sleep disorders in COPD after excluding samples with missing lung function data

To more accurately assess the relationship of sleep disorders with LSPT and DST in COPD, we excluded samples with missing lung function data and included totally 1739 cases (weighted population: 23,955,559). The FEV1, FVC, and rate were included as covariates in the regression model. The results showed that in model 1, model 2, and model 3, sleep disturbance was significantly associated with DST, while no significant correlation was observed between sleep disorder and LTPA (Table 4).

In addition, we performed subgroup analyses by age (40–60 or 60–80 years), sex (male or female), and BMI (<25, 25–30, or ≥30 kg/m^2). The age-based subgroup analysis revealed that DST was not significantly linked with sleep disorders in COPD samples aged 40–60 years. However, in aged 60–80 years, DST was significantly associated with sleep disorders (Table S6). Based on sex subgroup analysis, a significant association between DST and sleep disorders was observed only in

Table 3 Conjoint Association of Daily Sitting Time (DST) and Leisure-Time Physical Activity (LTPA) with Sleep Disorder of COPD Population

Sleep Disorder		Event N (Weighted)	OR (95% CI)			
LTPA, in/wk	**DST, h/d**		**Model 1**	**Model 2**	**Model 3**	**Model 4**
≥150	**<4**	45,631	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
	4–8	1,412,066	5.00(1.33, 18.8)	4.23(1.12, 16.0)	5.88(1.80, 19.2)	3.49(0.89, 13.7)
	>8	339,723	3.29(0.70, 15.5)	2.94(0.59, 14.6)	2.86(0.56, 14.7)	2.89(0.57, 14.7)
<150	**<4**	108,663	3.99(0.98, 16.2)	3.42(0.84, 13.9)	3.16(0.78, 12.9)	3.04(0.75, 12.4)
	4–8	468,356	7.27(2.03, 26.1)	5.95(1.67, 21.2)	5.47(1.52, 19.6)	5.20(1.45, 18.6)
	>8	1,168,804	9.75(2.93, 32.5)	7.44(2.23, 24.8)	6.50(1.93, 21.8)	5.88(1.80, 19.2)
≥150	**<4**	45,631	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
	≥4	552,617	5.21 (1.44, 18.8)	4.10 (1.08, 15.6)	4.10 (1.08, 15.6)	3.83 (1.03, 14.2)
<150	**<4**	465,188	3.99 (0.98, 16.2)	3.14 (0.78, 12.7)	3.14 (0.78, 12.7)	3.01 (0.74, 12.2)
	≥4	2,240,082	8.36 (2.47, 28.4)	5.79 (1.72, 19.5)	5.79 (1.72, 19.5)	5.37 (1.62, 17.8)

Notes: Model 1: Adjusted for age.group; Model 2: Multivariable model adjusted for sex, race, BMI, age; Model 3: Multivariable model adjusted for sex, race, BMI, age, comorbidity index; Model 4: Multivariable model adjusted for sex, race, BMI, age, comorbidity index, smoking, alcohol.
Abbreviations: OR, Odds Ratio; CI, Confidence Interval.

Table 4 Association of Daily Sitting Time (DST) and Leisure-Time Physical Activity (LTPA) with Sleep Disorder of COPD Population After Excluding Samples with Missing Lung Function Data

Sleep Disorder	Event N (Weighted)	OR (95% CI)		
		Model 1	**Model 2**	**Model 3**
LTPA, min/wk				
Inactive	1,773,234	—	—	—
Insufficient	494,881	0.97(0.48, 1.99)	1.00(0.50, 2.03)	1.04(0.51, 2.10)
Sufficient	603,171	0.68(0.43, 1.08)	0.68(0.42, 1.09)	0.70(0.44, 1.13)
***P* for tend**	—	0.12	0.14	0.20
Daily sitting time, h				
~4	423,476	—	—	—
4~6	423,476	1.89(0.99, 3.63)	1.90(0.99, 3.67)	1.89(0.98, 3.65)
6~8	446,430	1.96(0.95, 4.05)	1.90(0.91, 3.99)	1.88(0.89, 3.96)
8	1,223,498	2.46(1.32, 4.56)	2.36(1.27, 4.41)	2.35(1.26, 4.37)
***P* for tend**	—	0.011	0.018	0.020

Notes: Model 1: Multivariable model adjusted for sex, race, BMI, age, comorbidity index, smoking, alcohol, rate; Model 2: Multivariable model adjusted for sex, race, BMI, age, comorbidity index, smoking, alcohol, FEV1; Model 3: Multivariable model adjusted for sex, race, BMI, age, comorbidity index, smoking, alcohol, FVC.
Abbreviations: OR, Odds Ratio; CI, Confidence Interval.

men (Table S7). The BMI subgroup analysis results showed that DST was significantly associated with sleep disorders only when BMI < 25 kg/m^2, but not in other subgroups (Table S8). Notably, we discovered that sleep disorders in COPD patients was not associated with DST in the subgroup analysis of LTPA (Table S9).

Conjoint analyses of the association of LTPA and DST with sleep disorders in COPD patients after excluding samples with missing lung function data

The FEV1, FVC, and rate were included as covariates to explore the conjoint effect of LTPA and DST on sleep disorders in COPD patients (Table 5). The conjoint analysis results revealed that longer DST and lower LTPA were associated with the occurrence of sleep disorders in COPD patients. In model 3, the risk of sleep disorders in COPD patients with LTPA <150 min/wk and DST > 8h was 5.78 times that of baseline (LTPA≥150 min/wk and DST < 4h) (95% CI: 1.68–19.9).

Table 5 Conjoint Association of Daily Sitting Time (DST) and Leisure-Time Physical Activity (LTPA) with Sleep Disorder of COPD Population After Excluding Samples with Missing Lung Function Data

Sleep Disorder		Event N (Weighted)	OR (95% CI)		
LTPA, min/wk	**DST, h/d**		**Model 1**	**Model 2**	**Model 3**
≥**150**	**<4**	45,631	1 [Reference]	1 [Reference]	1 [Reference]
	4–8	284,442	3.46(0.87, 13.8)	3.39(0.85, 13.5)	3.30(0.84, 12.9)
	>8	105,940	2.96(0.60, 14.6)	2.93(0.59, 14.6)	3.02(0.61, 15.0)
<150	**<4**	377,845	2.90(0.72, 11.7)	2.92(0.72, 11.8)	2.85(0.71, 11.4)
	4–8	939,871	5.03(1.38, 18.3)	5.04(1.37, 18.5)	4.89(1.33, 17.9)
	>8	950,400	6.27(1.79, 21.9)	6.04(1.73, 21.1)	5.78(1.68, 19.9)
≥**150**	**<4**	45,631	1 [Reference]	1 [Reference]	1 [Reference]
	≥**4**	557,540	4.01(1.08, 14.9)	3.92(1.05, 14.6)	3.90(1.05, 14.5)
<150	**<4**	377,845	2.83(0.70, 11.5)	2.86(0.71, 11.6)	2.80(0.70, 11.3)
	≥**4**	1,890,271	5.39(1.58, 18.4)	5.33(1.55, 18.4)	5.19(1.51, 17.9)

Notes: Model 1: Adjusted for age group; Model 2: Multivariable model adjusted for sex, race, BMI, age; Model 3: Multivariable model adjusted for sex, race, BMI, age, comorbidity index; Model 4: Multivariable model adjusted for sex, race, BMI, age, comorbidity index, smoking, alcohol.
Abbreviations: OR, Odds Ratio; CI, Confidence Interval.

Meanwhile, the risk of sleep disorders in COPD patients with LTPA <150 min/wk and DST > 4h was 5.19 times that of baseline (95% CI: 1.51–17.9).

Discussion

More recently, accumulating evidence has suggested the crucial role of physical activity and sleep quality in COPD patients.[11] Hence, in this study, we conducted a rigorous analysis to explore the independent and combined effects of sedentary time and physical activity time on sleep disorders in COPD patients using LTPA and DST data from the NHANES. Notably, we found that long-term sedentary behavior was associated with elevated risk of sleep disorders in COPD patients.

Firstly, our work has indicated that over 10% of COPD patients have experienced sleep disorders. Numerous researches had reported the connection between sedentary behavior, physical activity, and sleep in the general population. For instance, a study from people older than 18 years old in southwestern Brazil found that adequate leisure physical activity was associated with good sleep quality on weekdays, and people who met moderate or high-intensity exercise recommendations were more likely to have good sleep quality.[39] Another meta-analysis discovered a significant effect of physical activity on sleep quality only in children, middle-aged and elderly adults, while not on sleep quality in young. Moderate and low-intensity physical activity significantly improved sleep quality, but high-intensity physical activity was not linked to sleep quality.[40] However, in our investigation, there was no significant correlation between physical activity and the risk of sleep disorders in COPD patients after adjusting by important variables. The reasons for this result were unclear, which might be connected to the following elements: 1. The varying physical and psychological needs for physical activity vary among different age groups;[40] 2. The causes of sleep disorders in COPD patients were different from the general population;[41,42] 3. In this study, we focused on activity time as a variable while not delving into the potential impacts of activity environment, intensity, and frequency on sleep disorders.[43–45]

Next, alarmingly, we noticed that the majority of COPD patients exhibited insufficient physical activity levels and prolonged sedentary habits. Sedentary time emerged as a significant risk factor for sleep disorders in COPD patients, yet its influence was modulated by factors such as gender, age, BMI, and lung function across various subgroups. Sedentary behavior might be an important risk factor for sleep quality. A meta-analysis of 16 studies suggested that sedentary behavior was associated with an increased risk of sleep disturbances and insomnia.[21] Another study in older populations found that the association between sedentary behavior and sleep disorders was more significant in women but not in men.[46] On the contrary, our study revealed that sedentary behavior was significantly linked to sleep disorders in men with

COPD, whereas such a significant correlation was not observed among women. This discrepancy could potentially be due to the varying characteristics exhibited by male and female COPD patients, including distinct lung sizes, lung functions, inflammatory responses, and clinical manifestations.[47–49] In addition, the effect of sedentary behavior on the overall samples remained consistent before and after including lung function parameters, but the results varied in age and BMI subgroup analyses. This might be due to COPD patients' sleep quality being associated with lung function parameters like the FEV1/FVC ratio.[42]

Based on emerging evidences, the 2020 Global Guidelines on Physical Activity and Sitting Behavior from the World Health Organization recommend reducing sedentary behavior and replacing it with physical activity for health benefits. In this study, we reported the association of the conjoint effects of physical activity and sedentary behavior with sleep disorders of COPD patients, and we found that the risk of sleep disorders in COPD patients with LTPA <150 min/wk and DST > 8h was 5.88 times that of LTPA≥150 min/wk and DST < 4h, highlighting the importance of reducing sedentary behavior as an intervention to reduce sleep disorders for COPD patients. A previous study of cancer populations in the US found that patients with DST > 8 h and LTPA < 150 min/wk had a 5.5 times greater risk of death than those with a DST < 4 hours and LTPA > 150 min/wk.[24] Another study of 149,077 Australian adults aged ≥45 years discovered that the longer sedentary time was linked to increased risk of all-cause mortality in the group with the least activity (LTPA < 150 min/wk), and moderate or high-intensity physical activity could counteract the risks associated with sedentary behavior.[50]

At present, the mechanisms that sedentary behavior had on affecting sleep quality in COPD patients remained unclear. It was well known that patients with COPD suffered from gas exchange disturbances and airflow limitation, which could potentially be a contributing factor to sleep disorders among these patients.[42] Prolonged inactivity resulted in vascular dysfunction, diminished cardiopulmonary function, and decreased muscle mass and strength,[51] all of which might exacerbate airflow limitation and impact gas exchange in COPD patients. According to the latest GOLD COPD report (2024), obstructive sleep apnea is still one of the crucial comorbidities for COPD patients.[52] In addition, sedentary behavior could increase the inflammatory response, which was one of the pathogenesis of both sleep disorders and COPD.[1,51,53] Furthermore, sedentary behavior might impact sleep quality in COPD patients with alterations in body temperature, metabolism, and endocrine function.[22] Collectively, reducing sedentary behavior is probably contributing to decrease systematic inflammatory responses, improve metabolism and endocrine functions,[51] thereby benefiting for the improvement of sleep quality of COPD patients. On the other hand, proper physical activity is quite helpful for COPD patients to maintain cardiorespiratory fitness and muscular physical fitness,[54] which are important aspects in improving sleep quality. These hypotheses warranted further experimental validation, and if the aforementioned mechanisms and associations were confirmed, it became imperative to integrate strategies to minimize sedentary behavior into the existing treatment and management approaches for COPD. For instance, the clinical doctors could emphasize the importance of light intensity physical activity, recommend proper supervised exercise programs and self-management mobile phone applications for the COPD patients with sleep disorder.

Our findings provided a deeper insight into the association of COPD patients' sleep disorders with physical activity and sedentary behavior using the objective data from representative COPD patients extracted from the NHANES survey. However, there are also several limitations in this present work. Firstly, we have to recognize the inherent limitation of a cross-sectional design, and our study has only established association rather than causation. Based on which, the association between physical activity, sedentary time and sleep disorders in COPD population should be explored and confirmed via a further investigation in the future, for example longitudinal study, which would be beneficial for the causality interpretation of the findings. Meanwhile, the objective limitation of the NHANES database was another aspect. For instance, there might be unavoidable measurement errors in the physical activity questionnaire, and rare medical treatment information of the patients could be obtained. Moreover, the current work was based on the data of US population, which has limited the generalizability of our findings. Secondly, since COPD was diagnosed using the criteria of pre-bronchodilator FEV1/FVC ratio, the possibility of excessive inclusion overestimated the number of COPD patients could not be ruled out. Thirdly, the NHANES database did not provide symptom information of the enrolled participants, which also brought a potential issue involving residual confounding factors, although we have included various covariates in the models.

In our future work, above limitations would be addressed in our locally clinical cohort study, meanwhile it is also an important goal to further optimize the activity status grouping/ standards in COPD population. After the further investigation in our locally clinical cohort study, more deepening related mechanism exploration would be the final purpose our research, thereby to provide more specific clinical management strategies for the patients.

Conclusion

In this nationwide cross-sectional study, sedentary behavior and physical inactivity have been indicated as common status in COPD patients. Subgroup analyses based on gender, age, BMI, and lung function have demonstrated that long-term sedentary behavior might be a risk factor for sleep disorders in COPD, independently of the duration of physical activity. Our findings have implied that reducing sedentary behavior should be an important intervention goal in the treatment and management of COPD patients with sleep disorders. Especially in COPD population with high risk of sleep disorder, more light intensity physical activity, physical activity-focused behavior change tools, and supervised exercise programs are probably good choices for the patients. In the future, studies may further explicate these correlations and provide evidence to quantify the timing, restrictions, and domains of sedentary behavior, providing references to developing interventions for COPD patients with sleep disorders.

Data Sharing Statement

The data analyzed during the current study are available in the NHANES repository [https://www.cdc.gov/nchs/nhanes/].

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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