Cross-Sectional Study

Chronic Low Back Pain and Sleep Disturbance in Adults in the US: The NHANES 2009-2010 Study

Ye Tong, MD[1], Xiao-Qing Zhang, MD[2], and Hao-Yuan Zhou, MD[1]

From: [1]Department of Orthopaedics, Suzhou Hospital of Anhui Medical University, Suzhou, China; [2]Department of Laboratory, Bozhou People's Hospital, Bozhou, China

Address Correspondence:
Hao-Yuan Zhou, MD
Department of Orthopaedics, Suzhou Hospital of Anhui Medical University
No.299, Bianhe Middle Road
Yongqiao District
Suzhou, 234000, China
E-mail: zhy_ssyy@163.com

Disclaimer: The study was funded by Anhui Medical University Youth Fund (2021xkj082).

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 07-27-2023
Revised manuscript received: 10-09-2023
Accepted for publication: 10-11-2023

Free full manuscript: www.painphysicianjournal.com

Background: Chronic low back pain (CLBP) is a significant health challenge with a high prevalence rate. Sleep disorders, which are prevalent among adults, have been linked with CLBP. However, the intricate relationship between sleep and pain adds complexity to our understanding of CLBP.

Objectives: To investigate the association between CLBP and sleep disorders, with a focus on the potential role of sleep disorders as a risk factor for CLBP.

Study Design: Cross-sectional study based on publicly available data from the National Health and Nutrition Examination Survey (NHANES) for one cycle (2009-2010).

Setting: The NHANES employs a complex, multistage probability sampling design to select a nationally representative sample.

Methods: In this study, we included patients aged 20 to 69 years from the NHANES 2009-2010 cycle. After eliminating cases with missing data, a total of 863 patients remained. Baseline characteristics were analyzed by stratifying patients based on their CLBP status to assess initial inter-group disparities. Due to age imbalances between groups, we employed a 1:1 propensity score matching (PSM) method, reducing the sample to 508 patients. The association between CLBP and trouble sleeping was investigated following this calibration using a multivariate logistic regression analysis.

Results: Upon categorizing the baseline characteristics of 863 patients based on CLBP, we identified that those within the CLBP group tended to be older and had a greater prevalence of health conditions, including cancer, hypertension, and cardiovascular disease (CVD). Notably, the prevalence of sleep disorders was higher in the CLBP group than in the non-CLBP group ($P < 0.001$). After implementing an age-based PSM for the 2 groups, 508 patients were selected from the initial 863 patients. After adjusting for various confounders using multivariate logistic regression, our analysis revealed a strong association between sleep disorders and an increased risk of CLBP.

Limitations: This is a cross-sectional study, and therefore causality cannot be established.

Conclusions: This study underscores the significant association between sleep disorders and an elevated risk of CLBP, highlighting the need for comprehensive management strategies that consider the role of sleep disorders in CLBP.

Key words: NHANES, chronic low back pain, sleep disturbance

Pain Physician 2024: 27:E255-E262

Low back pain presents a significant health challenge, with lifetime prevalence rates documented to exceed 80% (1). The sustained burden on patients and public health systems implies a deficiency in the existing management strategies for low back pain, a situation that is particularly pronounced in the case of chronic low back pain (CLBP) (2,3). CLBP is listed among the top 5 causes of disability globally, thereby imposing substantial demands on health care infrastructures (4).

Sleep disorders, which encompass conditions such as insomnia, sleep apnea, and circadian rhythm sleep-wake disturbances, are prevalent (5). According to reports, nearly 40% of adults in the United States (US) suffer from a sleep disorder (6), and a sizable portion of them experience sleep deficits more than 50% of the time each month (7). Typically, the incidence of sleep disorders escalates with advancing age, and this unhealthy pattern of sleeping elevates the risk of a number of illnesses, such as diabetes, hypertension, and cardiovascular disease (8-10). Moreover, a link has been demonstrated between sleep disorders and CLBP. According to research, those who have CLBP are more likely to have sleep disturbances, and poor sleep quality can make pain sensations severe (11-13). Although the association between poor sleep and persistent lower back pain is still up for debate, it seems to be bidirectional. Luo et al (14) also substantiated a potential bidirectional causal association between genetically predicted insomnia and CLBP through a Mendelian randomization study.

However, the fundamental mechanisms underlying the association between CLBP and sleep problems are still largely unknown, demanding additional study to clarify this relationship and to guide efficient therapy approaches. This study aims to investigate the association between CLBP and sleep disorders using data from the National Health and Nutrition Examination Survey (NHANES), with a particular focus on the potential role of sleep disorders as a risk factor for CLBP.

Methods

Study Population and Design

NHANES is a cross-sectional investigation aimed at assessing the health and nutritional status of non-institutionalized civilian adults and children in the United States. Data collection for NHANES is accomplished through home interviews and physical examinations conducted at mobile examination centers, covering topics such as demographics, socioeconomics, diet, and health. For our study, we employed data from the 2009-2010 NHANES cycle, which included an arthritis questionnaire for patients aged between 20 and 69 years. The Arthritis Questionnaire Section (ARQ) provides interview data relevant to Low Back Pain (LBP). CLBP was assessed using the variable ARQ024D (i.e., Had low back pain for 3 consecutive months) in accordance with the American College of Rheumatology's definition of chronic pain (15). After excluding patients with incomplete data on weight coefficient, CLBP, sleep disturbances, marital status, body mass index (BMI), cardiovascular disease (CVD), cancer, and drinking status, our study ultimately comprised 863 individuals (Fig. 1).

Sleep Disturbance

To acquire information on individuals' sleep status, we adopted the "Sleep Disorders" questionnaire from the NHANES household interview survey. The queries, "Ever told a doctor you had trouble sleeping?" and "Ever told by a doctor you have a sleep disorder?" were asked of the patients. Patients were categorized as having a sleep disorder if they answered 'yes' to either of the 2 questions. Conversely, if they answered 'no' to both questions, they were categorized as not having a sleep condition.

Covariates

The covariates in our analysis mostly classified into 3 categories: 1) Demographics: age, gender, race (Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Other race), family poverty-to-income ratio (PIR) (< 1, 1-3, > 3), marital status (never married, married/cohabiting, widowed/divorced/separated), and educational attainment (below high school, high school, above high school); 2) Medical conditions: BMI (< 18.5 for underweight; ≥ 18.5 and ≤ 24.9 for normal weight; ≥ 25 and ≤ 29.9 for overweight; ≥ 30 for obesity), hypertension, diabetes, CVD, and cancer; 3) Lifestyle: energy intake, physical activity (Physical activity over the past 30 days was classified into tertiles, specific to each gender, based on the metabolic equivalent (MET) distribution of the current NHANES sample. Low, moderate, and high were the 3 categories assigned to different levels of physical activity). Other factors included smoking status (nonsmoker: smoked 100 cigarettes in a lifetime; former smoker: smoked > 100 cigarettes in a lifetime; current smoker: smoked > 100 cigarettes in a lifetime and smoked at the time of survey), drinking status (nondrinker, 1-5 drinks per month; 5-10 drinks per month; and 10+ drinks per month).

Propensity Score Matching

We conducted propensity score matching (PSM) using the MatchIt software package (version 4.5.4) (16) to neutralize age discrepancies between the groups with and without CLBP. The nearest matching algorithm was employed with a 1:1 matching ratio, and the caliper value was established at 0.05.

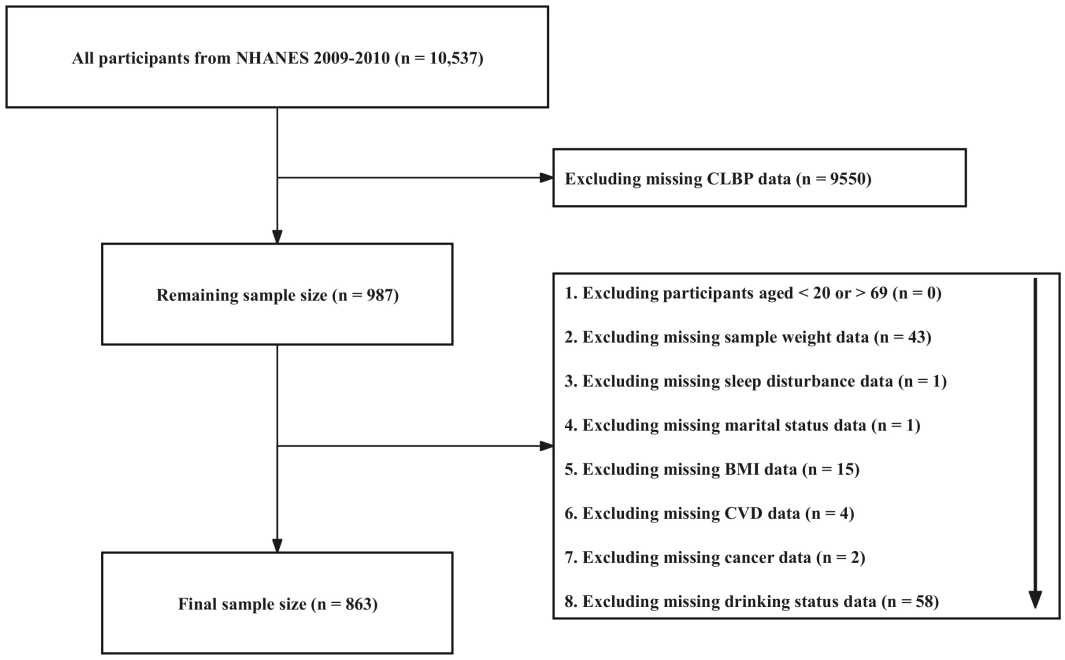

Fig. 1. *Flow chart of inclusion and exclusion for patients.*
Abbreviations: BMI, body mass index; CVD, cardiovascular disease; CLBP, chronic low back pain.

Statistical Methods

As categorical variables were marked by absolute numbers (%), continuous variables were represented by the mean (standard deviation). To evaluate group differences, the t test and chi-square test were applied. Multivariate logistic regression was used to investigate the association between CLBP and trouble sleeping. Outcomes were provided as odds ratios (OR) and 95% confidence intervals (CI). Model 1 was adjusted for age. Model 2 was further modified to incorporate modifications for gender, race, education, marital status, PIR, energy intake, and BMI. Finally, Model 3 had additional changes to take into account physical activity, alcohol use, cigarette smoking, hypertension, diabetes, CVD, and cancer. A *P*-value of 0.05 or less was regarded as statistically significant. R software (version 4.2.3) was used to perform all statistical analyses.

Results

As detailed in Table 1, the baseline characteristics of the study population are stratified by CLBP status. From the questionnaire results, 72% of patients were categorized under CLBP. They also had higher occurrences of conditions like hypertension ($P = 0.001$), CVD ($P = 0.018$), and cancer ($P = 0.030$). A notable observation was that 51.5% of the CLBP group reported sleep disorders, a proportion significantly higher than the 30.9% in the non-CLBP group ($P < 0.001$).

To balance age differences between groups, we utilized PSM, resulting in a subset of 508 patients drawn from the original 863 for in-depth analysis. Within this subset, 55% from the CLBP group and 30.2% from the non-CLBP group reported sleep disorders ($P < 0.001$), as depicted in Table 2. We then conducted multivariate logistic regression analyses on these patients. The initial model (Model 1), adjusted solely for age, showed an OR of 2.30 for sleep disorders influencing CLBP (OR = 2.30, 95% CI: 1.60-3.32, $P < 0.001$) (Fig. 2). After further adjustments, including age, race, education, marital status, PIR, energy intake, and BMI, the association between sleep disorders and a higher CLBP risk remained strong (OR = 2.29, 95%CI: 1.55-3.40, $P < 0.001$). In the fully adjusted model, this association persisted (OR = 2.21, 95%CI: 1.46-3.37, $P < 0.001$) (Fig. 3).

Discussion

A substantial body of prior research has determined that lower back pain primarily originates from disc degeneration, with common risk factors including genetic predispositions, age, obesity, smoking, and

Table 1. *Basic characteristics of patients with and without CLBP in NHANES 2009-2010.*

Characteristic	CLBP		*P* value
	No, n = 266 (28%)	Yes, n = 597 (72%)	
Gender			0.8
Female	135 (49.2%)	317 (51.2%)	
Male	131 (50.8%)	280 (48.8%)	
Age	42 (13.4)	46 (13.2)	< 0.001
Race			0.6
Non-Hispanic White	131 (68.5%)	329 (74.1%)	
Mexican American	60 (10.3%)	101 (8.0%)	
Non-Hispanic Black	38 (11.3%)	90 (9.6%)	
Other Hispanic	27 (5.9%)	59 (4.8%)	
Other race	10 (4.1%)	18 (3.5%)	
Education			0.7
Below high school	71 (18.7%)	168 (19.6%)	
High school	74 (23.9%)	155 (26.5%)	
Above high school	121 (57.4%)	274 (53.9%)	
PIR			0.6
< 1	71 (19.1%)	154 (16.6%)	
1-3	87 (29.6%)	223 (34.5%)	
> 3	83 (46.7%)	184 (44.1%)	
Unclear	25 (4.6%)	36 (4.8%)	
Marital status			0.6
Never married	51 (19.0%)	96 (17.7%)	
Married or cohabiting	166 (64.6%)	349 (62.9%)	
Widowed, divorced, or separated	49 (16.4%)	152 (19.4%)	
Energy intake	2,269 (918.0)	2,199 (908.0)	0.6
BMI			0.9
Underweight	2 (0.8%)	9 (1.7%)	
Normalweight	59 (20.8%)	117 (20.4%)	
Overweight	83 (31.7%)	186 (33.7%)	
Obesity	122 (46.7%)	285 (44.2%)	
Drinking status			0.064
Non-drinker	29 (6.2%)	84 (13.6%)	
1-5 drinks/month	145 (53.1%)	345 (52.6%)	
5-10 drinks/month	36 (13.7%)	56 (9.6%)	
10+ drinks/month	56 (27.1%)	112 (24.2%)	
Hypertension			0.001
No	170 (69.6%)	320 (59.7%)	
Yes	96 (30.4%)	277 (40.3%)	
Diabetes			0.4
No	102 (36.9%)	228 (37.4%)	
Yes	37 (9.2%)	111 (12.8%)	
Unclear	127 (53.8%)	258 (49.7%)	
CVD			0.018
No	248 (95.1%)	511 (88.8%)	
Yes	18 (4.9%)	86 (11.2%)	
Cancer			0.030
No	252 (94.7%)	536 (88.4%)	
Yes	14 (5.3%)	61 (11.6%)	
Smoking status			0.2
Nonsmoker	125 (46.7%)	230 (42.7%)	
Former smoker	51 (19.6%)	158 (27.3%)	
Current smoker	90 (33.7%)	209 (30.0%)	
Physical activity			0.3
Low	58 (23.7%)	111 (17.8%)	
Moderate	78 (32.5%)	162 (32.2%)	
High	66 (21.0%)	150 (27.6%)	
Unclear	64 (22.7%)	174 (22.5%)	
Sleep disorders			< 0.001
No	184 (69.1%)	291 (48.5%)	
Yes	82 (30.9%)	306 (51.5%)	

Table 1 cont. *Basic characteristics of patients with and without CLBP in NHANES 2009-2010.*

Abbreviations: CLBP, chronic low back pain; PIR, poverty-to-income ratio; BMI, body mass index; CVD, cardiovascular disease.

occupational factors (17,18). However, recent research has started to unravel the intricate relationship between sleep and pain, adding an additional layer of complexity to our understanding of CLBP. Sleep deficit is increasingly being associated with alterations in pain perception (19-21). Although previous studies have demonstrated a bidirectional association between pain and sleep, sleep disorders often have a higher predictive value for pain than pain does for sleep disorders (22,23).

Utilizing the NHANES data from the 2009-2010 cycle for US adults, our findings indicate that individuals with CLBP were predominantly older and had a higher likelihood of conditions like hypertension, CVD, and cancer. The incidence of sleep disorders was notably higher among those with CLBP compared to their counterparts without this condition. After offsetting the imbalance in age between the 2 groups of patients by PSM, we adjusted for covariates to construct multiple logistic regression models, and the results consistently endorsed that sleep disorders are highly associated

Table 2. *Baseline characteristics after PSM to correct for age disparities between patients in the CLBP and Non-CLBP groups (NHANES 2009-2010).*

Characteristic	CLBP		*P* value
	No, n = 254 (50%)	Yes, n = 254 (50%)	
Gender			0.7
Female	128 (48.5%)	137 (51.4%)	
Male	126 (51.5%)	117 (48.6%)	
Age	42 (13.3)	41 (13.3)	0.4
Race			> 0.9
Non-Hispanic White	125 (68.7%)	137 (69.8%)	
Mexican American	57 (10.1%)	46 (9.7%)	
Non-Hispanic Black	35 (10.7%)	35 (9.8%)	
Other Hispanic	27 (6.2%)	25 (5.6%)	
Other race	10 (4.3%)	11 (5.2%)	
Education			0.8
Below high school	66 (18.4%)	74 (21.1%)	
High school	71 (24.6%)	57 (22.9%)	
Above high school	117 (57.0%)	123 (56.0%)	
PIR			0.3
< 1	68 (19.1%)	66 (15.8%)	
1-3	83 (29.8%)	103 (37.9%)	
> 3	78 (46.3%)	69 (40.3%)	
Unclear	25 (4.9%)	16 (5.9%)	
Marital status			0.5
Never married	47 (17.6%)	51 (19.5%)	
Married or cohabiting	161 (67.2%)	146 (62.2%)	
Widowed, divorced, or separated	46 (15.2%)	57 (18.3%)	
Energy intake	2,298 (910.6)	2,204 (1,031.2)	0.3
BMI			0.7
Underweight	2 (0.9%)	5 (2.3%)	
Normalweight	56 (19.7%)	53 (20.2%)	
Overweight	79 (32.7%)	81 (30.2%)	
Obesity	117 (46.7%)	115 (47.3%)	
Drinking status			0.022
Non-drinker	27 (5.8%)	36 (14.5%)	
1-5 drinks/month	139 (53.7%)	144 (53.8%)	
5-10 drinks/month	34 (13.6%)	27 (12.5%)	
10+ drinks/month	54 (26.9%)	47 (19.2%)	
Hypertension			0.3
No	158 (67.8%)	152 (63.6%)	
Yes	96 (32.2%)	102 (36.4%)	
Diabetes			> 0.9
No	97 (37.5%)	109 (37.6%)	
Yes	37 (9.8%)	35 (8.9%)	
Unclear	120 (52.7%)	110 (53.5%)	
CVD			0.2
No	236 (94.8%)	225 (90.7%)	
Yes	18 (5.2%)	29 (9.3%)	
Cancer			0.024
No	241 (95.5%)	229 (89.0%)	
Yes	13 (4.5%)	25 (11.0%)	
Smoking status			0.8
Nonsmoker	120 (47.5%)	104 (44.5%)	
Former smoker	51 (20.7%)	61 (23.7%)	
Current smoker	83 (31.8%)	89 (31.8%)	
Physical activity			0.2
Low	56 (24.5%)	42 (17.5%)	
Moderate	75 (32.6%)	64 (27.3%)	
High	61 (19.2%)	72 (30.1%)	
Unclear	62 (23.7%)	76 (25.1%)	
Sleep disorders			< 0.001
No	174 (69.8%)	124 (45.0%)	
Yes	80 (30.2%)	130 (55.0%)	

Table 2 cont. *Baseline characteristics after PSM to correct for age disparities between patients in the CLBP and Non-CLBP groups (NHANES 2009-2010).*

Abbreviations: PSM, propensity score matching; CLBP, chronic low back pain; PIR, poverty-to-income ratio; BMI, body mass index; CVD, cardiovascular disease.

with an elevated risk of CLBP. Insomnia and obstructive sleep apnea (OSA) emerged as the most prevalent diagnoses in studies evaluating the influence of sleep disorders on pain outcomes. A diagnosis of OSA notably elevated the likelihood of chronic pain reporting, as well as heightened pain intensity and sensitivity. These symptoms could be mitigated by treatment-induced sleep (24). Recent research has demonstrated that sleep deprivation amplifies pain responses in crucial perceptual regions of the cerebral cortex while it dampens activity in other areas responsible for pain regulation. By reducing pain thresholds, sleep deprivation broadens the spectrum of intensities at which stimuli are perceived as painful (25).

A single night of total sleep deprivation can compromise downstream pain pathways, enhance spinal cord excitability, and increase the sensitivity of peripheral pathways to cold and pressure-induced pain (26). Sleep disturbances influence pain pathways at multiple

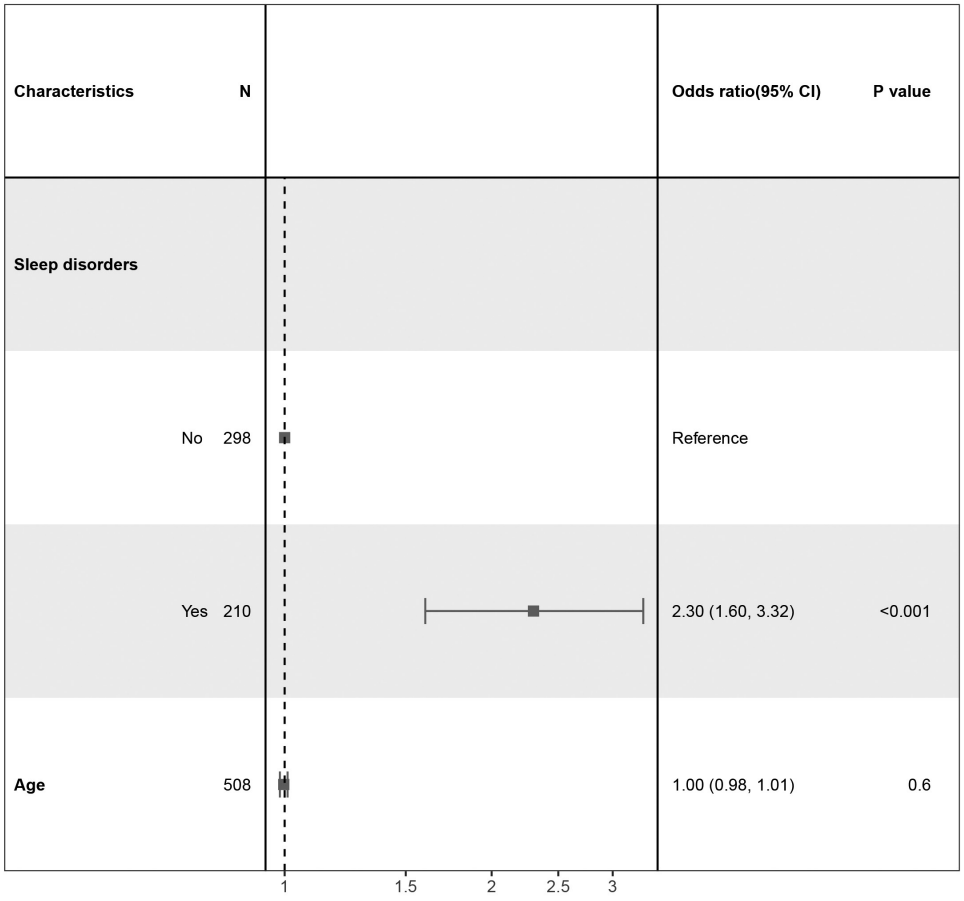

Fig. 2. *Forest plot of the odds ratio for the association between sleep disorders and risks of CLBP (model 1: adjusted for age).*
Abbreviations: CI, confidence interval.

anatomical levels, instigating a shift towards proinflammation in the immune system and amplifying spinal pain transmission. Additionally, these disturbances impact the mesolimbic system, a critical player in the emotional and cognitive facets of pain, potentially exacerbating the pain experience (27). The short, fragmented, and poor-quality sleep frequently endured by chronic pain patients can intensify pain symptoms, creating a vicious cycle of heightened sensitivity to various painful stimuli (28).

Despite the high prevalence of lower back pain, the prognosis is generally positive. However, nearly 2/3 of patients continue to experience pain 3 months after the onset of the condition. Among the clinical interventions for patients with CLBP, pharmacological treatments, such as nonsteroidal anti-inflammatory drugs, are the most commonly utilized nonsurgical options (29). However, as of now, the management of sleep issues has not been extensively integrated into interventions for patients with CLBP.

Our study presents several limitations. Firstly, the data pertaining to sleep disorders and CLBP was gathered via a questionnaire, potentially introducing recall bias. Secondly, omitting samples due to incomplete information may have induced selection bias. Moreover, while we accounted for several confounders in our multivariate logistic regression analysis, potential unmeasured or unrecognized confounding factors could still impact the results. Lastly, given the cross-sectional nature of this study, we cannot deduce a causal link between sleep disorders and CLBP.

Conclusions

The present study reveals a significant correlation

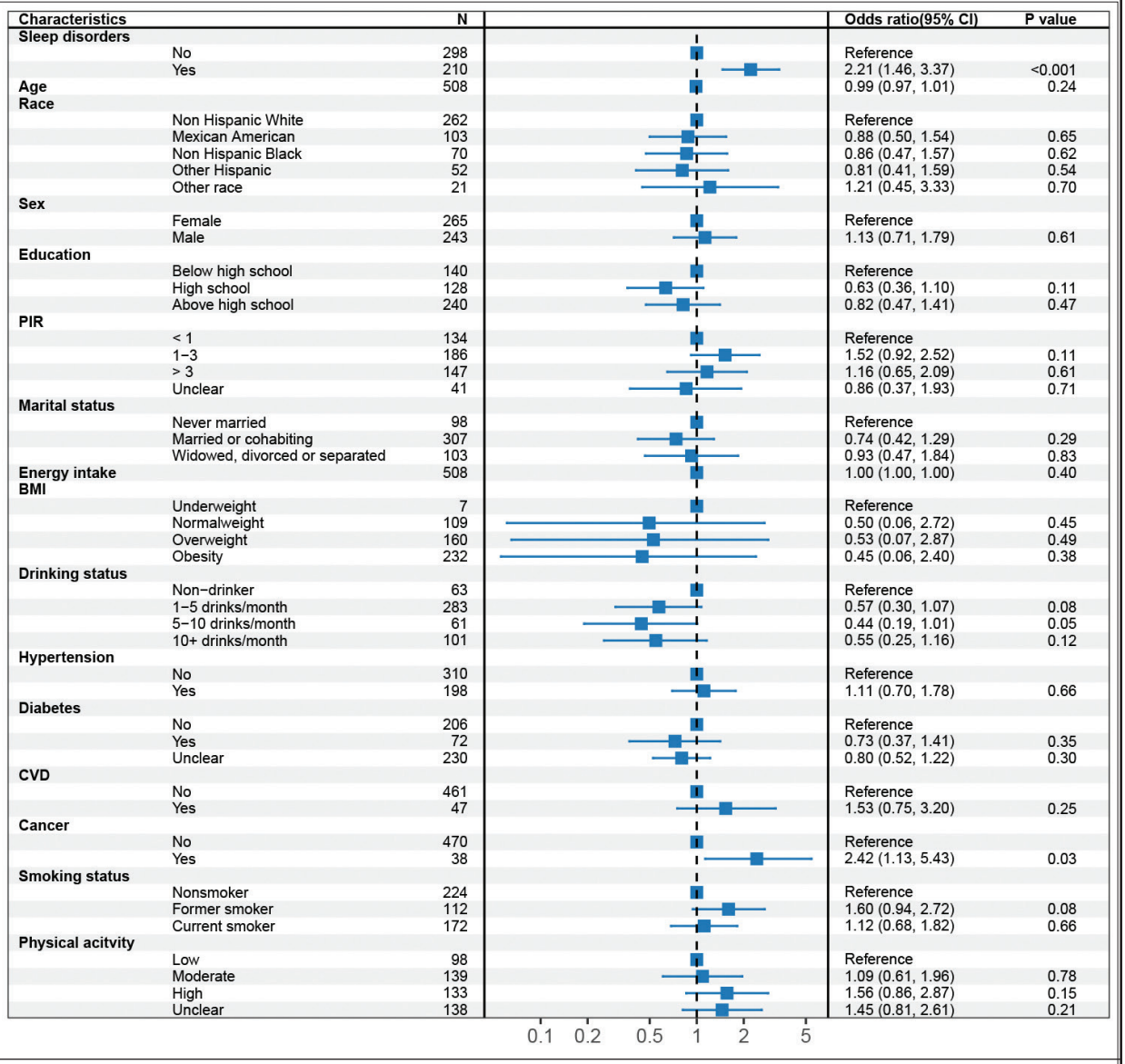

Fig. 3. *Forest plot of the odds ratio for the association between sleep disorders and risks of CLBP (model 3: adjusted for age, gender, race, education, marital status, PIR, energy intake, BMI, physical activity, alcohol use, cigarette smoking, hypertension, diabetes, CVD, and cancer).*
Abbreviations: CI, confidence interval; PIR, poverty-to-income ratio; BMI, body mass index; CVD, cardiovascular disease.

between sleep disorders and CLBP. Concentrating on the commonly co-occurring complaints of sleep issues in patients with CLBP appears to be a vital extension to pain management. This focus can be quite beneficial in preventing symptom progression and achieving a more satisfactory therapeutic outcome.

References

1. Enthoven WT, Roelofs PD, Deyo RA, van Tulder MW, Koes BW. Non-steroidal anti-inflammatory drugs for chronic low back pain. *Cochrane Database Syst Rev* 2016; 2:CD012087.
2. Lansing JE, Ellingson LD, DeShaw KJ, Cruz-Maldonado G, Hurt TR, Meyer JD. A qualitative analysis of barriers and facilitators to reducing sedentary time in adults with chronic low back pain. *BMC Public Health* 2021; 21:215.
3. Knox PJ, Coyle PC, Pugliese JM, Pohlig RT, Sions JM, Hicks GE. Hip osteoarthritis signs and symptoms are associated with increased fall risk among community-dwelling older adults with chronic low back pain: a prospective study. *Arthritis Res Ther* 2021; 23:71.
4. Schultz MJ, Licciardone JC. The effect of long-term opioid use on back-specific disability and health-related quality of life in patients with chronic low back pain. *J Osteopath Med* 2022; 122:469-479.
5. Deng MG, Nie JQ, Li YY, Yu X, Zhang ZJ. Higher HEI-2015 scores are associated with lower risk of sleep disorder: Results from a nationally representative survey of United States adults. *Nutrients* 2022; 14:873.
6. Chamine I, Atchley R, Oken BS. Hypnosis intervention effects on sleep outcomes: Asystematic review. *J Clin Sleep Med* 2018; 14:271-283.
7. Johnson DA, Lewis TT, Guo N, et al. Associations between everyday discrimination and sleep quality and duration among African-Americans over time in the Jackson Heart Study. *Sleep* 2021; 44:zsab162.
8. Chee JK, Yeat CL, Abdulkareem ZA, Barton-Burke M. Non-pharmacological interventions for the treatment of sleep-wake disturbances in patients with cancer. *Cochrane Database Syst Rev* 2018; 2018:CD011576.
9. Ishibashi F, Tavakoli M. Thinning of macular neuroretinal layers contributes to sleep disorder in patients with type 2 diabetes without clinical evidences of neuropathy and retinopathy. *Front Endocrinol* 2020;11:69.
10. Tranah GJ, Yaffe K, Nievergelt CM, et al. APOEε4 and slow wave sleep in older adults. *PLoS One* 2018; 13:e0191281.
11. Marty M, Rozenberg S, Duplan B, et al. Quality of sleep in patients with chronic low back pain: A case-control study. *Eur Spine J* 2008; 17:839-844.
12. Roseen EJ, Gerlovin H, Femia A, et al. Yoga, physical therapy, and back pain education for sleep quality in low-income racially diverse adults with chronic low back pain: A secondary analysis of a randomized controlled trial. *J Gen Intern Med* 2020; 35:167-176.
13. Steinmetz A, Hacke F, Delank KS. Pressure pain thresholds and central sensitization in relation to psychosocial predictors of chronicity in low back pain. *Diagnostics (Basel)* 2023; 13:786.
14. Luo G, Yao Y, Tao J, Wang T, Yan M. Causal association of sleep disturbances and low back pain: A bidirectional two-sample Mendelian randomization study. *Front Neurosci* 2022; 16:1074605.
15. Wolfe F, Smythe HA, Yunus MB, et al. The American College of Rheumatology 1990 criteria for the classification of fibromyalgia. *Arthritis Rheum* 1990; 33:160-172.
16. Ho DE, Imai K, King G, Stuart EA. MatchIt : Nonparametric preprocessing for parametric causal inference. *J Stat Softw* 2011; 42:1-22.
17. Liu C, Zhu C, Li J, et al. The effect of the fibre orientation of electrospun scaffolds on the matrix production of rabbit annulus fibrosus-derived stem cells. *Bone Res* 2015; 3:15012.
18. Traeger AC, Buchbinder R, Elshaug AG, Croft PR, Maher CG. Care for low back pain: Can health systems deliver? *Bull World Health Organ* 2019; 97:423-433.
19. Wuestenberghs F, Melchior C, Desprez C, Leroi AM, Netchitailo M, Gourcerol G. Sleep quality and insomnia are associated with quality of life in functional dyspepsia. *Front Neurosci* 2022; 16:829916.
20. Gerhart JI, Burns JW, Post KM, et al. Relationships between sleep quality and pain-related factors for people with chronic low back pain: Tests of reciprocal and time of day effects. *Ann Behav Med* 2017; 51:365-375.
21. Seminowicz DA, Remeniuk B, Krimmel SR, et al. Pain-related nucleus accumbens function: Modulation by reward and sleep disruption. *Pain* 2019; 160:1196-1207.
22. Desjardins S, Lapierre S, Hudon C, Desgagné A. Factors involved in sleep efficiency: A population-based study of community-dwelling elderly persons. *Sleep* 2019; 42:zsz038.
23. Koffel E, Kroenke K, Bair MJ, Leverty D, Polusny MA, Krebs EE. The bidirectional relationship between sleep complaints and pain: Analysis of data from a randomized trial. *Health Psychol* 2016; 35:41-49.
24. Saconi B, Polomano RC, Compton PC, McPhillips MV, Kuna ST, Sawyer AM. The influence of sleep disturbances and sleep disorders on pain outcomes among veterans: A systematic scoping review. *Sleep Med Rev* 2021; 56:101411.
25. Krause AJ, Prather AA, Wager TD, Lindquist MA, Walker MP. The pain of sleep loss: A brain characterization in humans. *J Neurosci* 2019; 39:2291-2300.
26. Staffe AT, Bech MW, Clemmensen SLK, Nielsen HT, Larsen DB, Petersen KK. Total sleep deprivation increases pain sensitivity, impairs conditioned pain modulation and facilitates temporal summation of pain in healthy participants. *PLoS One* 2019; 14:e0225849.
27. Kourbanova K, Alexandre C, Latremoliere A. Effect of sleep loss on pain—New conceptual and mechanistic avenues. *Front Neurosci* 2022; 16:1009902.
28. Faraut B, Léger D, Medkour T, et al. Napping reverses increased pain sensitivity due to sleep restriction. *PLoS One* 2015; 10:e0117425.
29. Gianola S, Bargeri S, Del Castillo G, et al. Effectiveness of treatments for acute and subacute mechanical non-specific low back pain: A systematic review with network meta-analysis. *Br J Sports Med* 2022; 56:41-50.