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Association of leisure-time physical activity and sleep quality among healthcare workers in China: a cross-sectional study

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Abstract

Background Growing evidence suggests that insufficient physical activity is a risk factor for poor sleep quality. However, few studies have investigated their relationship in healthcare workers. This study aims to fill this research gap by assessing the association between leisure-time physical activity and sleep quality among healthcare workers in China.

Methods Our data came from a cross-sectional study conducted from October to December 2022. Using stratified random sampling, we collected behavioral and health data from 2,896 healthcare workers in Shanghai. We applied multiple linear and logistic regressions to assess the association between leisure-time physical activity and sleep quality measured by the Pittsburgh Sleep Quality Index (PSQI), controlling for confounders.

Results Among the 2,896 participants included in the analytical sample, the prevalence of sleep disturbance was 62.88% and the average PSQI score was 6.94 (SD = 3.45). Sleep disturbance was associated with nurses and other occupations, chronic diseases, stress, and increased workload. Leisure-time physical activity (OR = 0.770 (0.651, 0.911), $p = 0.002$) was a significant protective factor of sleep disturbance.

Conclusions Leisure-time physical activity may be a protective factor for sleep quality among healthcare workers in China. Actionable policies and interventions, such as paid time off and subsidized gym membership, should be invested to increase physical activity among Chinese healthcare workers and, ultimately, improve their sleep quality and overall health.

Keywords Physical activity, Sleep quality, Healthcare worker, China, Cross-sectional study

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Background

Healthcare workers are facing a serious problem of poor sleep quality [1]. According to a study, 61.0% of nurses suffered from poor sleep quality [2]. In a Greek research, 58.2% of healthcare workers who worked shifts were dissatisfied with the quality of their sleep [3]. The average Pittsburgh Sleep Quality Index (PSQI) score of healthcare workers in 30 emergency medical service agencies in the United States was 6.9, higher than the normal sleep quality standard 5 [4, 5]. A 2018 systematic review of 52 Chinese cross-sectional or longitudinal studies showed that 39.2% of Chinese healthcare workers suffered from sleep disorders, higher than the general population [6]. Low sleep quality is common and increasing among healthcare workers, putting them at risk for decreased immunity, impaired attention, and compromised decision-making [7, 8].

The nature of healthcare work itself exacerbates these challenges. Studies indicate that sleep quality deterioration among healthcare workers is intensified in high-stress clinical environments. For instance, in 2020, almost all U.S. healthcare workers reported poor sleep, with 30% experiencing moderate to severe insomnia [9]. Similarly, a 2022 survey in Shanghai revealed that 84% of primary healthcare workers with elevated stress levels exhibited significant deterioration in at least one sleep dimension, with evidence linking high stress to sleep disorder risks [10]. The observed sleep deterioration is strongly associated with occupational stressors, and these challenges are exacerbated by increased workload, psychological stressors, and insufficient workplace support systems, particularly for frontline workers [11–15].

Studies have shown that physical activity, as well as individual-level factors, socioeconomic status (SES) and wellness are related to sleep quality [16]. Current research results show that the impact of exercise on sleep quality may be dual-sided. Liu H et al. [17] and Han Y et al. [18] found that lack of physical activity is one of the high-risk factors for sleep disorders among healthcare workers. Some studies showed that those who engage in physical exercise report poorer sleep quality less frequently, and physical activity is beneficial for sleep quality at all ages [19–22]. On the other hand, high physical workload and excessively frequent intense exercise at work are considered to be associated with difficulty falling asleep [23].

In healthcare institutions operating around the clock, workers are regularly exposed to irregular shift patterns and extended working hours, known contributors to sleep disturbances and circadian dysfunction [24, 25]. Poor sleep quality can lead to physical fatigue in healthcare workers and even lead to medical accidents, threatening patient safety and the quality of medical services [26]. Different from other jobs, healthcare workers have the characteristics of high workload, on-call duties, and occupational hazards. Therefore, it's urgent to pay attention to their sleep quality. Given the seriousness of sleep issues among healthcare workers and the complexity of physical activity as a factor influencing sleep, more research evidence is needed to better understand the impact of exercise on the sleep of healthcare workers.

This cross-sectional study aimed to clarify the relationship between sleep quality and leisure-time physical activity in healthcare workers in China. We hypothesize that healthcare workers have poor sleep quality and their leisure-time physical activity is inversely proportional to their PSQI score.

Methods

Study design

This cross-sectional study adopted a mixed-method approach to identify the influencing factors of sleep quality in healthcare workers in Shanghai, focusing on the association between leisure-time physical activity and sleep quality. The study was conducted among healthcare workers between 1 November and 31 December 2022 in urban, suburban and rural areas of Shanghai since Shanghai has geographical differences. The inclusion criteria were as follows: (1) those who were aged ≥ 18 years old (2), those who were full-time healthcare workers at the investigated hospitals, and (3) those who voluntarily participated in this study. The exclusion criteria were: (1) participants with diagnosed sleep disorders or psychiatric disorders and (2) those who refuse to cooperate. According to a previous systematic review on sleep quality in Chinese healthcare workers, which found that the prevalence of sleep disturbances was 45.1%, the sample size for our study was estimated based on this prevalence, with a minimum required sample size of 2,254 [12].

Data collection

Our "Shanghai Healthcare Workers Occupational Health Questionnaire" was designed based on previous research and our pre-survey in a hospital. Depending on regional economic development, we selected four central urban administrative districts, two outskirts administrative districts (usually rural areas), and two suburban administrative districts in Shanghai. We planned to select three tier-1 hospitals (also named community health service centers), one tier-2 hospital, and one tier-3 hospital from each district randomly. It is worth noting that typical tier-3 hospitals are often concentrated in urban areas, so we only sampled tier-3 hospitals in urban areas. According to the minimum sample size, the proportion of medical staff size and the number of medical institutions at each level, we planned to recruit 3080 participants, draw 45, 100 and 300 people from selected tier-1, tier-2 and tier-3 hospitals respectively, calculated by the following equation, $300*4 + 100*(4 + 2 + 2) + 45*3*(4 + 2 + 2) = 308$

0. We contacted the hospital's administrative office and distributed the web-based (www.wjx.cn) questionnaire to healthcare workers. 2910 participants were recruited, and the questionnaire response rate was 2910/3080 = 94.48%.

Measurement

The primary outcome variable was sleep quality, which was assessed by the PSQI. The Chinese adaptation of this instrument has validated in Chinese populations, demonstrating robust internal consistency (Cronbach's $\alpha = 0.842$) and established construct validity [27]. The PSQI is a self-rated questionnaire consisting of 18 items to evaluate seven aspects of sleep in the previous month, including sleep quality, latency, duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Due to the uncorrectable time formatting issues, we adjusted the calculation method of hours in bed. The original method used go-to-bed time (Q1) and get-up time (Q3), while our adjusted method used the time required to fall asleep (Q2) and actual sleep hours (Q4). Each component scores from 0 to 3, with the global score ranging from 0 to 21. Higher scores indicate poorer sleep quality. Participants with a global score > 5 were classified as having sleep disturbances [5].

The explanatory variables included four aspects. The first was the leisure-time physical activity which was assessed by asking the participants whether they had leisure-time physical activity in the past month [28]. The second aspect was individual-level factors, including gender, age, marital status (married, unmarried and others), and ethnicity (the Han Chinese or others). Four SES-related variables were measured, including education (college degree or below, bachelor's degree, master's degree or Ph.D. degree), occupation (doctor, nurse or others), monthly income (< 10000 CNY, ≥ 10000 CNY and < 20000 CNY or ≥ 20000 CNY), and perceived workload variation (no significant change/ increased/ reduced). The last aspect evaluated the wellness of healthcare workers via the following questions: Do you suffer from the following chronic diseases (coronary heart disease/ stroke/ hypertension/ diabetes/ cancer / others /no)? Stress: How is your perception of pressure in the last month (low/ fair/ high)?

Statistics

All collected data were analyzed using SPSS Statistics 25.0 and R 4.2.1. After removing the records of individuals with uncorrectable errors ($N = 14$), such as age formatting, 2896 eligible participants were included (99.52%). We described results for continuous variables with normal distributions by mean ± standard deviation (SD), and outcomes for discrete variables were displayed as numbers (N) and percentages (%). The correlation was calculated using Pearson's method. We analyzed the differences in the participants' PSQI scores for each aspect according to explanatory variables using analysis of variance (ANOVA). Factors that influence participants' PSQI scores were analyzed using multiple linear regression analyses. Finally, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using logistic regression to estimate the strength of the association between sleep disturbance and predictors. Two-sided $p < 0.05$ was considered to be statistically significant.

Results

General characteristics

Table 1 presents the general characteristics of the 2896 healthcare workers who participated in this study, including 700 males (24.17%) and 2196 females (75.83%). The mean age was 38.33 years old (SD = 8.54). Most were married (78.28%) and Han Chinese (98.17%). Of the participants, 44.1% were doctors and 36.5% were nurses. More than half of the participants had a bachelor's degree (64.30%) and had a personal monthly income below ¥10 000 (62.29%). Most participants (82.67%) said that the COVID-19 pandemic had increased their workload. One-fifth of the participants were suffering from chronic diseases, 58.67% reported a high level of perceived stress in the previous month. Approximately two-thirds of the participants had never exercised in the last month. The mean PSQI score was 6.94 (SD = 3.45), and according to the PSQI score, 62.86% of participants were considered to have significant sleep disturbances.

Association between different characteristics and sleep quality

The result of correlation analysis indicated that individual health factors such as higher stress levels ($r = 0.361$, $P < 0.001$), chronic disease ($r = 0.145$, $P < 0.001$) have a significant unhealthy impact on sleep quality. As for gender, females are relatively poor sleepers ($r = 0.086$, $P < 0.001$). Meanwhile, participants with higher income (r = -0.124, $P < 0.001$) and education (r = -0.085, $P < 0.001$) had better sleep quality. Increased perceived workload ($r = 0.100$, $P < 0.001$) Moreover, the PSQI score was significantly lower in the presence of leisure-time physical activity (r = -0.118, $P < 0.001$).

The bar plots in Fig. 1 delineated the association between different factors and PSQI components. According to the result of ANOVA, variables with significant differences in means are shown in different colors, while those with no significant differences are shown in grey. We found that 'Gender', 'Chronic disease' and 'Stress' affected every component. Each aspect of PSQI except 'Use of sleep medication' was associated with 'Leisure-time physical activity'. Overall, the included variables have stronger associations with sleep latency, sleep efficiency,

Table 1 General characteristics information of healthcare workers investigated

Variables	*N* / Mean	% / SD
Gender		
Male	700	24.17
Female	2196	75.83
Age*	38.33	8.54
Marital status		
Married	2267	78.28
Unmarried	539	18.61
Others	90	3.11
Ethnic		
Han	2843	98.17
Minority	53	1.83
Education		
College degree or below	394	13.60
Bachelor's degree	1862	64.30
Master's degree	484	16.71
Ph.D. degree	156	5.39
Occupation		
Doctor	1277	44.10
Nurse	1057	36.50
Others	562	19.41
Monthly income(¥)		
< 10,000 CNY	1804	62.29
≥ 10,000 CNY and < 20,000 CNY	950	32.80
≥ 20,000 CNY	142	4.90
Workload		
No significant change	405	13.98
Increase	2394	82.67
Decrease	97	3.35
Chronic disease		
Yes	624	21.55
No	2272	78.45
Stress		
Low	176	6.08
Fair	1021	35.26
High	1699	58.67
Leisure-time physical activity		
Yes	1048	36.19
No	1848	63.81
PSQI*	6.94	3.45
Component 1: Sleep quality*	1.24	0.78
Component 2: Sleep latency*	1.14	0.92
Component 3: Sleep duration*	1.37	0.77
Component 4: Habitual sleep efficiency*	0.08	0.34
Component 5: Sleep disturbance*	1.11	0.70
Component 6: Use of sleep medication*	0.26	0.72
Component 7: Daytime dysfunction*	1.74	1.00
Sleep disturbance		
Yes	1821	62.88
No	1075	37.12

and sleep disturbances while less impact on sleep duration, medication usage and daytime dysfunction.

Multiple linear regression analysis of influencing factors of sleep health

We incorporated leisure-time physical activity in each model. Except for leisure-time physical activity, Model 1 (Adjusted R^2: 0.025, $p < 0.001$) was also adjusted for individual-level factors. Model 2 (Adjusted R^2: 0.05569, $p < 0.001$) was adjusted for SES-related factors based on Model 1. Model 3, additionally adjusted for individual health factors after COVID-19 of Model 2, was found to be significant ($F = 32.275$, $p < 0.001$), and the adjusted R^2 indicate the model's explanatory power was 0.186.

Table 2 shows the results of the multiple regression analysis. According to Model 3, significant factors related to sleep quality included having leisure-time physical activity (B = -0.591 (-0.838, -0.344), $p < 0.001$), female (B = 0.421 (0.119, 0.722), $p = 0.006$), having a married or unmarried marital status (B = 1.064 (0.391, 1.736), $p = 0.002$), monthly income ≥ 10,000 CNY and < 20,000 CNY (B = -0.518 (-0.793, -0.242), $p < 0.001$) and ≥ 20,000 CNY (B = -0.888 (-1.492, -0.285), $p = 0.002$),, having increased workload (B = 0.547 (0.195, 0.9), $p < 0.001$), having chronic disease (B = 1.165 (0.867, 1.463), $p < 0.001$), and stress (Fair: B = 1.091 (0.577, 1.606), $p < 0.001$; High: B = 2.979 (2.467, 3.49), $p < 0.001$).

Risk and protective factors for sleep disturbance

The results of multivariate logistic regression analysis (Fig. 2) showed that compared with the reference group, nurse (OR = 1.347(1.071, 1.694), $p = 0.011$), having increased workload (OR = 1.431(1.133, 1.807), $p = 0.003$), having chronic diseases (OR = 1.792 (1.439, 2.232), $p < 0.001$), and higher stress (Fair: OR = 2.251 (1.585, 3.198), $p < 0.001$; High: OR = 5.599 (3.934, 7.970), $p < 0.001$) were risk factors of sleep disturbance. Leisure-time physical activity (OR = 0.770 (0.651, 0.911), $p = 0.002$) and higher income (≥ 10000 CNY and < 20000 CNY: OR = 0.752 (0.623 to 0.908), $p = 0.003$; ≥20000 CNY: OR = 0.615 (0.416, 0.920) were protective factors of sleep disturbance.

Discussion

This study investigated the sleep quality and its relevant factors among Chinese healthcare workers, with a particular focus on the role of leisure-time physical activity(LTPA). The results of this study showed that healthcare workers in Shanghai had low sleep quality, which is consistent with the results shown in studies from other regions [29, 30]. LTPA emerged as a significant protective factor of sleep quality, as evidenced by its negative association with PSQI score (B = -0.591, $p < 0.001$) and reduction in the odds of sleep disturbance

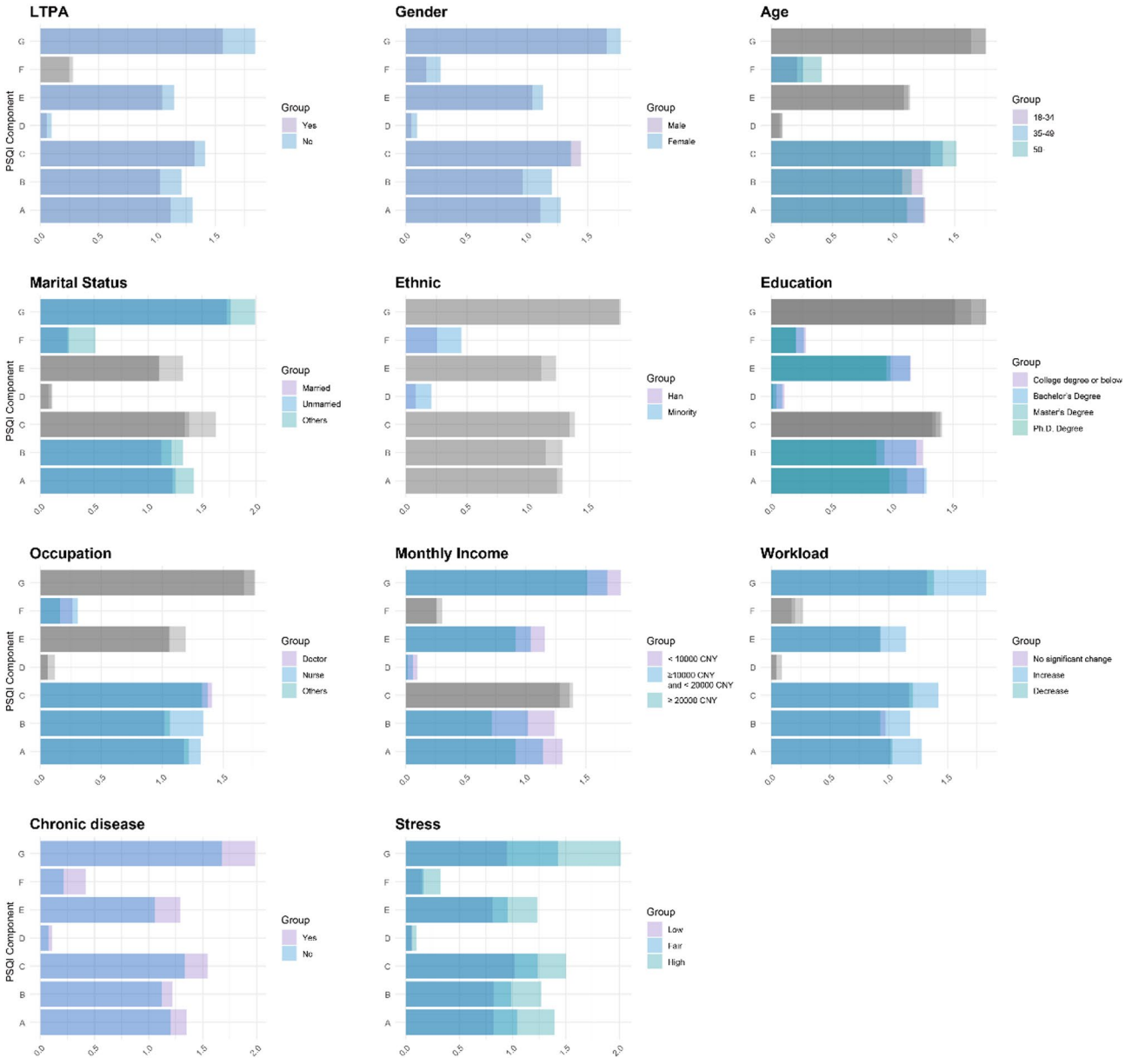

Fig. 1 Bar plots for each PSQI component by explanatory factors. **A**: Sleep quality; **B**: Sleep latency; **C**: Sleep duration; **D**: Habitual sleep efficiency; **E**: Sleep disturbance; **F**: Use of sleep medication; **G**: Daytime dysfunction

(OR = 0.770, $p = 0.002$). Alongside LTPA, gender, education, income, perceived workload variation, chronic disease and stress were also linked to sleep outcomes. These results underscore the multifaceted nature of sleep health in healthcare workers, highlighting LTPA as a modifiable protective behavior of sleep quality.

Study population demonstrated a mean PSQI score of 7.23 (SD = 3.73), with 64.6% of Shanghai healthcare workers meeting criteria for sleep disturbances. Notably, longitudinal comparisons revealed persistent sleep impairments compared to earlier acute service demand periods. Ying Zhao et al. [31] found a global PSQI score of 6.00 during April-June 2022 lockdowns. Similarly, Ping Wang et al. [32] identified 55.9% sleep disturbance prevalence using different thresholds in May 2022. Three potential explanations may account for these discrepancies: First, inclusion of diverse healthcare roles in our study likely captured subgroups with elevated sleep vulnerability. Second, diagnostic heterogeneity persists across studies - while Wang's team applied PSQI > 6 cut-off [32], our threshold followed PSQI > 5, increasing case identification sensitivity. Third, the dramatic decrease in non-COVID patient visits during the acute pandemic phases subsequently manifested as a sudden influx of these patients during our survey period, and directly translated to a sharp rise in workloads for healthcare

Table 2 Multiple linear regression analysis of influencing factors of sleep quality

	Variables	MODEL1		MODEL2		MODEL3	
		B (95%CI)	*P*-value	B (95%CI)	*P*-value	B (95%CI)	*P*-value
Leisure-time physical activity	**Leisure-time physical activity**						
	No	Ref.	-	Ref.	-	Ref.	-
	Yes	**-0.807 (-1.071, -0.543)**	**<0.001**	**-0.639 (-0.901, -0.378)**	**<0.001**	**-0.591 (-0.838, -0.344)**	**<0.001**
Individual-level factors	**Gender**						
	male	Ref.	-	Ref.	-	Ref.	-
	Female	**0.560 (0.265, 0.856)**	**<0.001**	0.211 (-0.107, 0.528)	0.193	**0.421 (0.119, 0.722)**	**0.006**
	Age						
	≥ 18 and < 34	Ref.	-	Ref.	-	Ref.	-
	≥ 35 and < 49	-0.04 (-0.358, 0.279)	0.807	0.142 (-0.181, 0.465)	0.389	-0.093 (-0.402, 0.216)	0.555
	≥ 50	0.235 (-0.233, 0.704)	0.325	**0.524 (0.044, 1.003)**	**0.032**	0.200 (-0.267, 0.668)	0.400
	Marital status						
	Married	Ref.	-	Ref.	-	Ref.	-
	Unmarried	0.132 (-0.246, 0.51)	0.494	0.170 (-0.207, 0.547)	0.377	0.249 (-0.108, 0.606)	0.171
	Others	**1.394 (0.672, 2.116)**	**<0.001**	**1.371 (0.661, 2.082)**	**<0.001**	**1.064 (0.391, 1.736)**	**0.002**
SES-related factors	**Education**						
	College degree or below			Ref.	-	Ref.	-
	Bachelor's degree			0.280 (-0.113, 0.672)	0.162	0.119 (-0.253, 0.491)	0.53
	Master's degree			-0.091 (-0.620, 0.438)	0.737	-0.237 (-0.74, 0.265)	0.354
	Ph.D. degree			-0.046 (-0.768, 0.676)	0.901	-0.365 (-1.05, 0.32)	0.296
	Occupation						
	Doctor			Ref.	-	Ref.	-
	Nurse			0.137 (-0.212, 0.486)	0.442	0.246 (-0.084, 0.576)	0.144
	Others			-0.323 (-0.682, 0.036)	0.078	-0.04 (-0.38, 0.301)	0.818
	Monthly income						
	< 10,000 CNY			Ref.	-	Ref.	-
	≥ 10,000 CNY and < 20,000 CNY			**-0.492 (-0.784, -0.201)**	**0.001**	**-0.518 (-0.793, -0.242)**	**<0.001**
	≥ 20,000 CNY			**-1.141 (-1.779, -0.504)**	**<0.001**	**-0.888 (-1.492, -0.285)**	**0.004**
	Workload						
	No significant change			Ref.		-	
	Increase			**1.316 (0.954, 1.678)**	**<0.001**	**0.547 (0.195, 0.9)**	**0.002**
	Decrease			0.223 (-0.527, 0.973)	0.559	0.158 (-0.551, 0.867)	0.662
Individual health factors	**Chronic disease**						
	No					**Ref.**	**-**
	Yes					**1.165 (0.867, 1.463)**	**<0.001**
	Stress						
	Low					Ref.	-
	Fair					**1.091 (0.577, 1.606)**	**<0.001**
	High					**2.979 (2.467, 3.49)**	**<0.001**

workers. Fourth, other important influencing factors of sleep quality, such as the sociodemographic characteristics, healthy lifestyle and health status, may not had changed significantly.

Our findings prove evidence that LTPA significantly associates with improved sleep quality in healthcare workers, aligning with various studies which have revealed this association in multiple ways and domains [33, 34]. In the case of China, relatively few studies have been conducted on the relationship between LTPA and sleep quality among healthcare workers. As for the healthcare workers, previous studies by Qixiu Li et al. [35] and Huan Liu et al. [36] consistently reported that LTPA serves as a protective factor for healthcare workers, and is particularly evident in high-stress environments. However, our study offers a unique perspective by

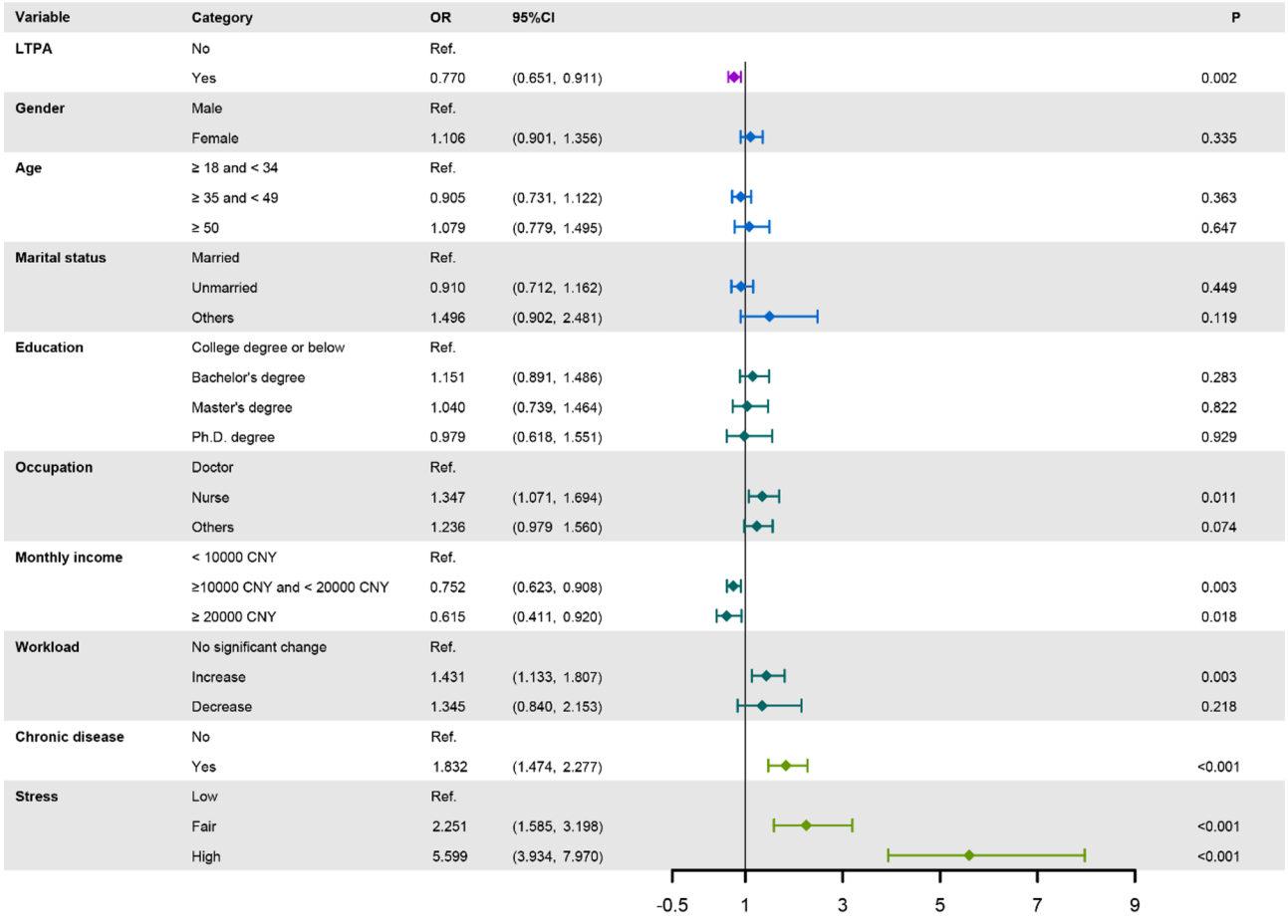

Fig. 2 Logistic regression analysis of risk and protective factors for sleep disturbance

including samples from primary healthcare institutions, extending the scope beyond previous studies, which largely concentrated on tertiary hospitals. Some studies focused on the effects of traditional Chinese exercises such as Tai Chi [37–39], Qigong, and Wuqinxi [40] reported improvements in the PSQI. The significance varied in scores for sleep quality, sleep-onset latency, sleep duration, sleep efficiency, and sleep disturbances. Although the target populations in these studies—often older or retired individuals—differ from our working-age sample, these studies offer valuable insights for healthcare interventions aimed at improving sleep with low-cost and convenient exercise programs.

Several studies also explained the relationship between physical activity and sleep quality from a biological perspective, with physiological changes produced during physical activity improving sleep quality. For instance, physical activity may decrease cortisol levels [41] and alter the plasma concentration of the many pro-inflammatory cytokines [42], which may in turn improve sleep. Similarly, light exposure [43], temperature regulation, and mood were also seen as potential mechanisms of action for physical activity to affect sleep in older adults [44].

The sleep problems of healthcare workers have caused a severe adverse impact on their physical health and work efficiency. Countries have proposed relevant interventions. The UK provided mental health-related support and guidance to relieve stress and improve sleep quality [45]. In addition, Australia and New Zealand have educated healthcare workers about sleep to provide them with relevant knowledge and skills [46]. Denmark helped healthcare workers improve their sleep quality by reducing night work complexity and decision-making speed [46]. Based on the robust association between LTPA, perceived workload variation, stress and sleep quality found in this study, we recommend that Chinese medical staff should appropriately enhance sports, treat work pressure correctly, and combine work and rest. In terms of hospital management, we should increase the number of medical staff, reduce the workload, extend the shift cycle, and improve medical staff treatment. For social support, it is suggested that relatives and friends provide care and support, which is beneficial to eliminate the work burden of medical staff.

Our results can serve as a valuable resource for decision-makers, helping them make informed decisions based on the evidence, and promoting leisure-time physical activity among healthcare workers. However, this study has some limitations. Firstly, while physical activity is our primary research variable, we lack detailed measures such as its intensity, frequency, and duration. This limitation of our physical activity measurement approach prevented us from detecting the finer gradations of exercise characteristics, such as dose-response relationship [47], thereby potentially overlooking critical effect modifiers. Secondly, PSQI is a self-report index, it can only obtain subjective answers from participants, which may lead to bias. While PSQI is widely used, future study could benefit from using multiple and objective variables, such as polysomnography, actigraphy, and sleep diary, to measure healthcare workers' physical activity and sleep quality. Thirdly, we only conducted surveys in Shanghai, and thus our sample may not be representative of healthcare workers in rural or remote areas of China. The findings cannot capture regional variations in the healthcare workers' lifestyles, work stressors, and access to resources. In addition, due to the practical challenges in collecting data from all potential participants, we were unable to produce absolute random sampling. Moreover, due to the simplification of our questionnaire in order to maximize response rate, there are several confounding factors not accounted for in our study, such as occupational physical activity, sedentary behavior, smoking, and alcohol consumption, all of which could potentially influence sleep quality. Some factors, such as health status, workload, and stress, were also measured by into single questions to further streamline the survey. The omission and simplification of these factors may contribute to the relatively low adjusted R^2 value in our regression models. Future research should control for these variables to provide a clearer understanding of the relationship between physical activity and sleep quality. Lastly, our data cannot draw causal conclusions since this is a cross-sectional study. Future longitudinal studies are needed to improve our understanding of the relationship between physical activity and sleep quality.

Conclusion

In conclusion, this study adds to the growing body of evidence linking leisure-time physical activity to sleep quality. Having no leisure-time physical activity was significantly associated with sleep disturbance among healthcare workers in China. Thus, actionable policies and interventions, such as paid time off and subsidized gym membership, should be invested to increase physical activity among Chinese healthcare workers and, ultimately, improve their sleep quality and overall health.

Abbreviations

PSQI	Pittsburgh Sleep Quality Index
SES	Socioeconomic status
OR	Odds ratio
CI	Confidence interval
SD	Standard deviation
N	Numbers
ANOVA	Analysis of variance

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Not applicable.

Author contributions

J.H. provided the idea and conceived the framework of the article. J.S. collected questionnaires and data. YG.Y. conducted the statistical analysis, and made figures and tables. YQ.Y. contributed to the introduction and manuscript organization. J.G., P.Z., B.T., and L.C. all participated in the writing of the discussion section. Y.L., J.H., J.G., and J.S. were responsible for reviewing the article and revising the submitted version.

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Data availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Declarations

Ethics approval and consent to participate

The studies involving human participants complied with the Declaration of Helsinki and were reviewed and approved by The ethics committees of Shanghai Tenth People's Hospital (ref: 2019-K173-02). The patients/participants provided their written informed consent to participate in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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