

Stress and sleep: a survey based on wearable sleep trackers among medical and nursing staff in Wuhan during the COVID-19 pandemic

Kaiming Zhuo,^{1,2} Cunyou Gao,^{2,3} Xiaohui Wang,^{2,4} Chen Zhang,^{1,2} Zhen Wang ^{1,2}

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ABSTRACT

Background COVID-19 pandemic has significantly affected the sleep health of local medical and nursing staff.

Aim We used wearable pulse oximeters to monitor and screen the medical and nursing staff working in hospitals designated for COVID-19 in the Wuhan area. This study aimed to establish a reliable basis to provide sleep intervention for the medical and nursing staff.

Methods Thirty medical and nursing staff members with symptoms of insomnia were instructed to wear medical ring-shaped pulse oximeters to monitor their sleep overnight. We also used the Insomnia Severity Index (ISI) and the Chinese version of the Self-Reporting Questionnaire (SRQ-20) to evaluate the severity of insomnia and mental health status, respectively, for each participant.

Results Among the 30 participants, only 26 completed the screening. Ten cases (38.5%) demonstrated moderate to severe sleep apnoea–hypopnea syndrome (SAHS) when using an oxygen desaturation index ≥ 15 times/hour as the cut-off value. Participants with comorbid moderate to severe SAHS had significantly higher ISI and SRQ scores (p values 0.034 and 0.016, respectively) than those in the insomnia group. Correlation analysis revealed that ISI was positively correlated with total sleep time (TST) ($r=0.435$, $p=0.026$), and negatively correlated with deep sleep ($r=-0.495$, $p=0.010$); furthermore, patient SRQ scores were positively correlated with TST, sleep efficiency (SE) and REM (rapid eyes movement) sleep % ($r=0.454$ and 0.389 , 0.512 ; $p=0.020$, 0.050 and 0.008 , respectively). Stepwise logistic regression indicated that SRQ-20 and sex were risk factors for insomnia with comorbid SAHS, and their OR values were 1.516 and 11.56 (95% CI 1.053 to 2.180 and 1.037 to 128.9), respectively.

Conclusion Medical and nursing staff with insomnia showed clear signs of comorbid sleep apnoea attributable to stress. The wearable pulse oximeters accurately monitored the participants' breathing when asleep.

Since December 2019, there have been several cases of an acute respiratory disease occurring in Wuhan City, Hubei Province in China. This disease, which was originally known as novel coronavirus pneumonia and later as the COVID-19,^{1–3} has spread rapidly from Wuhan to the rest of the world. Currently,

more than 1 million cases of COVID-19 have been confirmed globally, and the WHO has declared the COVID-19 outbreak a global pandemic.⁴ This pandemic has significantly affected the mental health of local medical and nursing staff. Kang *et al*⁵ reported that among the mental health of 994 medical and nursing staff working in Wuhan during the epidemic, 22.4% demonstrated moderate to high levels of depression, anxiety and insomnia, with 6.2% being diagnosed with severe levels of the same.

Sleep is an indispensable physiological process in maintaining physical health. When facing stressful situations, individuals will need to respond to drastic changes in the external environment, which may cause symptoms such as sleep suppression and increased wakefulness, thus increasing the occurrence of insomnia (including difficulty falling asleep, difficulty maintaining sleep and waking up early), daytime sleepiness, nightmares and daytime dysfunction, among other sleep-related disorders.⁶ Sleep apnoea–hypopnea syndrome (SAHS) is a common sleep disorder that primarily manifests in the form of obstructive sleep apnoea–hypopnea syndrome (OSAHS). Approximately 14% of men and 5% of women suffer from OSAHS.⁷ Although OSAHS clinically presents with sleepiness and is considerably different from insomnia, an increasing number of studies have shown that OSAHS often coexists with insomnia. Furthermore, the prevalence of comorbid insomnia in OSAHS patients may be as high as 67.4%.⁸ Conditions that are traumatic and stressful may exacerbate insomnia resulting in disturbed sleep and increased duration of stage 1 light sleep; consequently, these frequent changes in sleep phases further increase upper airway instability and aggravate OSAHS symptoms.⁹ Comorbidity of OSAHS and insomnia in stressful conditions



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¹Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China

²Shanghai Psychological First Aid Team for Wuhan, Shanghai, China

³Shanghai Jiading Mental Health Center, Shanghai, China

⁴Shanghai Qingpu Mental Health Center, Shanghai, China

Correspondence to

Dr Zhen Wang;
wangzhen@smhc.org.cn

may further amplify physical harm by increasing the risk of cardiovascular and cerebrovascular diseases.^{10,11} Therefore, it is imperative to monitor the medical and nursing staff diagnosed with OSAHS and comorbid insomnia in the current scenario.

Wearable medical pulse oximeters were administered to monitor and screen the medical and nursing staff working in COVID-19 designated hospitals in the Wuhan area and evaluate their mental health to elucidate the psychological and physiological effects of stress on sleep and breathing. We hope that our findings will provide a reliable basis to administer sleep intervention to the pertinent medical and nursing staff members.

DATA AND METHODS

This study was implemented in March 2020.

Participants

We included medical and nursing staff members working in Wuhan Children's Hospital, Wuhan Central Hospital and other COVID-19 designated hospitals between January and March 2020. Prior to their enrolment, the participants were clinically evaluated by psychiatrists in the Shanghai Psychological First Aid Team for Wuhan.

Inclusion criteria

Patients (1) aged ≥ 18 years; (2) frequently presenting with symptoms of nocturnal insomnia, such as difficulty in falling asleep, difficulty in maintaining sleep and waking up early, which were accompanied by daytime fatigue, decline in attention or memory, impulsiveness and irritability, sleepiness and other symptoms since they began participating in COVID-19 efforts, as well as meeting the ICSD-3 (International Classification of Sleep Disorders-3) diagnostic criteria for short-term insomnia; (3) who have not taken benzodiazepine or non-benzodiazepine sedative hypnotics within the past month; and (4) who have provided a written informed consent.

Exclusion criteria

(1) Patients with concomitant cardiovascular, lung, liver, kidney, hematopoietic and other severe primary diseases and those with severe organic brain disease and mental illnesses; (2) patients with a history of alcoholism or use of other psychoactive substances; and (3) pregnant or breastfeeding women.

Medical ring-shaped pulse oximeter is a new type of wearable preliminary sleep screening instrument that can monitor pulse rate and blood oxygen changes overnight. Pulse rate indicators include mean pulse rate, minimum/maximum pulse rate and nocturnal pulse elevation index (ie, the number of sleeping heart rate fluctuations > 6 times/min). Blood oxygen indicators include oxygen desaturation index (ODI_4 ; ie, the number of times blood oxygen saturation decreases by $\geq 4\%$ per hour), mean percutaneous oxygen saturation ($MSpO_2$), percentage of total sleeping time spent with blood oxygen saturation

$< 90\%$ (TS 90%), among others. Studies conducted in China and globally have shown that ODI_4 is positively correlated with the Apnoea-Hypopnea Index, and an $ODI_4 \geq 15$ times/hour was considered to provide an adequate degree of sensitivity and specificity to screen moderate to severe OSAHS.¹²

The Insomnia Severity Index (ISI) is an instrument developed by Morin *et al* to measure the self-perceived symptoms of insomnia in the prior 2 weeks.¹³ Compared with the Pittsburgh Sleep Quality Index and Epworth Sleepiness Scale, the ISI specifically assesses the severity of insomnia. ISI includes seven items, is relatively simple and convenient to administer and has a high level of empirical validity. It has been widely applied in clinical research and has demonstrated an excellent degree of consistency and effectiveness in reflecting the quality of sleep.

The Self-Reporting Questionnaire (SRQ-20) is a questionnaire developed by the WHO to screen for mental disorders and was designed specifically for developing countries. It consists of 20 questions, each of which may be scored as 0 or 1, and a higher score indicates a higher prominence of symptoms associated with mental disorders. Previously, this questionnaire was applied in the postdisaster mental health survey of the population, and it demonstrated considerably consistency reliability and criterion-related validity.¹⁴

Statistical analysis

Statistically analysis was performed using SPSS V.19.0. Measurement data obtained by monitoring were expressed as $\chi(-) \pm s$, and count data as percentage (%). T-tests and non-parametric Wilcoxon tests were respectively performed based on whether the data were normally distributed or not; χ^2 tests were performed to compare the incidences between two groups. We used the Pearson and Spearman correlation to analyse normally distributed and non-normally distributed measurement data, respectively. Stepwise logistic regression was performed to analyse the independent risk factors of insomnia with comorbid OSAHS. $P < 0.05$ indicated that the difference was statistically significant.

RESULTS

General demographics and questionnaire survey

Forty-nine medical and nursing staff members were screened of which 30 enrolled. Finally 26 participants (14 men and 12 women) completed the study. The participant demographics, along with the questionnaire results are presented in [table 1](#). The monitoring results of medical pulse oximetry are shown in [table 2](#).

Analysis of ring-shaped pulse oximetric monitoring indicators

The total sleep time (TST), sleep efficiency (SE), light sleep stage, deep sleep stage, REM sleep stage, ODI , frequency of oxygen desaturation, TS90%, $MSpO_2$ and mean pulse rate were monitored using the pulse oximeter, and their results are shown in [table 2](#). Using $ODI \geq 5$

Table 1 General demographics and questionnaire results

Item	Mean (SD) (n=26)
Age (year)	41.92 (9.32)
Sex (male/female, case)	14/12
BMI (kg/m ²)	23.41 (2.86)
ISI	7.69 (5.11)
SRQ-20	4.19 (3.47)

BMI, body mass index; ISI, Insomnia Severity Index; SRQ-20, Self-Reporting Questionnaire.

times/hour as the cut-off value for classification revealed that 14 cases (53.8%) presented with SAHS. Considering the fact that an ODI ≥15 times/hour was used to classify moderate to severe disorder, 10 cases (38.5%) were found to have moderate to severe SAHS.

Using the cut-off value of ODI ≥15 times/hour, we categorised the participants with an ODI <15 times/hour into the insomnia group, while those with ≥15 times/hour to the comorbid moderate to severe SAHS group, following which an intergroup comparison was performed. We used the non-parametric Wilcoxon test since both sets of data were not normally distributed. The results of the same are presented in [table 3](#).

Given the significant intergroup differences with regard to the number of male and female participants, the analysis of covariance was performed with the patient sex as a covariate. The results indicated that the intergroup differences for ISI, SRQ, ODI, TS90% and MSpO₂ remained statistically significant (F=7.738, 7.472, 114.9, 6.925 and 11.64, p=0.011, 0.012, 0.000, 0.015 and 0.002, respectively).

Spearman correlation analysis for age, sex, ISI and SRQ with the various sleep indicators revealed that ISI was positively correlated with SRQ and TST (r=0.685, 0.435; p<0.001 and p<0.026) and negatively correlated with deep sleep (r=-0.495, p=0.010); furthermore, SRQ was

Table 2 Results of pulse oximetry

Item	Mean (SD) (n=26)
Total sleep time (min)	442.0 (55.0)
Sleep efficiency (%)	86.37 (4.93)
Light sleep stage (%)	46.63 (8.06)
Deep sleep stage (%)	20.88 (6.09)
REM sleep stage (%)	19.18 (4.13)
ODI	16.16 (17.49)
Frequency of oxygen desaturation	123.92 (136.58)
TS90%	4.61 (10.22)
MSpO ₂	62.00 (7.08)
Mean pulse rate	62.00 (7.08)

MSpO₂, mean percutaneous oxygen saturation; ODI, oxygen desaturation index; TS90%, percentage of time spent at SpO₂ below 90%.

positively correlated with TST, SE and REM% (r=0.454, 0.389, 0.512; p=0.020, 0.050 and 0.008, respectively).

Stepwise logistic regression

Stepwise multiple logistic regression was performed using the presence of SAHS as the dependent variable, along with other variables such as age, sex, BMI, ISI score, SRQ-20 score and sleep quality (see [table 4](#)). The outcome of the χ^2 test performed after including SRQ-20 and sex in the regression equation was as follows: $\chi^2(-) = 11.84, p=0.003$; considering which, the regression equation was statistically significant. Therefore, the SRQ-20 score and patient sex were considered to be risk factors for insomnia with comorbid SAHS, and their OR values were 1.516 and 11.56 (95% CI 1.053 to 2.180 and 1.037 to 128.9), respectively.

DISCUSSION

Main findings

Outcomes of the screening conducted in this study revealed that the incidence of comorbid moderate to severe SAHS in insomnia patients was 38.5% (10/26). However, using a cut-off value of ODI ≥5 times/hour demonstrated that the proportion of SAHS patients with comorbid insomnia was even higher (53.8%). This finding further validates the outcomes of previous investigations using polysomnography. Guilleminault *et al*¹⁵ first proposed the concept of OSAHS comorbid with insomnia in 1973, while Krakow *et al*¹⁶ reported that OSAHS comorbidity was clinically significant in more than 50% of insomnia patients. The high comorbidity rate of OSAHS and insomnia suggests that these two diseases may not be purely concomitant but may share common pathophysiological mechanisms. In addition, the overactivation of the hypothalamic–pituitary–adrenal (HPA) axis under stress may be the link between the two.

In cases of traumatic stress, acute stress suppresses REM sleep and increases the duration of non-REM sleep, which is followed by restorative sleep compensation, increased sleep time and increased REM sleep.¹⁷ However, persistent or repeated chronic stress exposure may have a more negative impact on sleep, resulting in the presentation of sleep disorders, insomnia and other problems.¹⁸ In the presence of an active HPA axis, individuals may experience a lighter sleep, increasing awakenings and sleep fragmentation.¹⁹ Fragmented sleep can subsequently excite the sympathetic catecholamine system and elevate cortisol levels, which eventually results in persistent insomnia.²⁰ Repeated awakenings and an increased frequency of light sleep can also lead to frequent sleep phase changes and upper airway instability, thereby exacerbating SAHS symptoms.²¹ SAHS-induced decrease in blood oxygen saturation generates hypoxic stress, which further activates the HPA axis while increasing the patients' breathing rate to maintain adequate alveolar ventilation. This results in repeated microarousals during

Table 3 Intergroup comparison of characteristics and sleep parameters of participants

Group	Insomnia group (n=16)	Comorbid SAHS group (n=10)	Z/ χ^2 (-)	P value
Age	41.68 (10.33)	42.30 (7.95)	0.106	0.916
Sex (male/female, case)	6/10	8/2	4.473	0.034*
BMI	22.77 (2.61)	24.42 (3.09)	1.476	0.140
ISI	5.87 (4.28)	10.60 (5.16)	2.115	0.034*
SRQ	2.87 (3.07)	6.30 (3.12)	2.415	0.016*
TST (min)	432.31 (59.34)	457.60 (45.85)	1.081	0.280
SE (%)	85.77 (4.48)	87.33 (5.69)	0.659	0.510
LS (%)	46.33 (9.17)	47.11 (6.31)	0.211	0.833
DS (%)	21.50 (5.81)	19.90 (6.70)	1.107	0.268
REM (%)	17.94 (2.45)	21.19 (5.50)	1.450	0.147
ODI	3.58 (2.87)	36.29 (10.25)	4.217	p<0.001*
Frequency of oxygen desaturation	27.37 (17.21)	278.40 (90.76)	4.219	p<0.001*
TS90%	0.51 (1.63)	11.17 (14.42)	3.393	p<0.001*
MSpO ₂	97.28 (1.59)	94.43 (2.04)	3.374	0.001*
Pulse rate, P	59.87 (7.31)	65.40 (5.42)	2.218	0.027*

*p<0.05

BMI, body mass index; DS, deep sleep stage; ISI, Insomnia Severity Index; LS, light sleep stage; MSpO₂, mean percutaneous oxygen saturation; ODI, oxygen desaturation index; SE, sleep efficiency; SRQ, self-reporting questionnaire; TS90%, percentage of time spent at SpO₂ below 90%; TST, total sleep time.

sleep, which disrupts the continuity and periodicity of sleep, which further fragments the sleep cycle.²²

The Insomnia Severity Index (ISI) has demonstrated an acceptable degree of consistency and validity in reflecting the severity of insomnia.¹³ Our screening results showed that participants with insomnia and comorbid SAHS scored higher on the ISI than those with insomnia alone, and ISI was negatively correlated with the duration of deep sleep. These findings indicated that the lack of deep sleep continues to be the main cause of insomnia and that SAHS is a key factor responsible for the fragmentation and superficialisation of the sleep process.²² ISI was positively correlated with TST ($r=0.435$, $p=0.026$), which is inconsistent with the outcomes of previous studies that have reported a decrease in subjective and objective TST in insomnia patients. This may be attributed to the concomitant presentation of insomnia and SAHS that may further damage the sleep structure; alternatively, it may be due to the relatively small sample size of this study.

The self-reporting questionnaire (SRQ-20) has been translated into more than 10 languages for use in the

corresponding regions around the world, and each version has been scrutinised for its reliability and validity.^{14 23 24} Jiang *et al*¹⁴ studied the reliability and validity of the Chinese version of the SRQ-20, which was administered 3 weeks after the Wenchuan earthquake, and reported that this questionnaire had an acceptable degree of consistency reliability and criterion-related validity in reflecting the postdisaster traumatic stress experienced by victims. In this study, participants with insomnia and comorbid SAHS showed significantly higher SRQ scores than those with insomnia alone. The results of logistic regression analysis also indicated that the SRQ-20 score was a risk factor for insomnia with comorbid SAHS, with a higher score indicating a greater risk for insomnia with comorbid SAHS. This finding suggested that SAHS comorbidity may further introduce psychological problems in individuals who had previously experienced traumatic stress. Some studies have shown that OSAHS patients often concomitantly present with depression and anxiety, which are the factors that significantly contribute to a decline in their quality of life and lead to incidence rates of 34%–56%.²⁵

Table 4 Logistic regression prediction model parameters for sleep perception disorders

Item	Regression coefficient β	SE	Wald	OR	95% CI	P value
Sex	2.448	1.230	3.957	11.56	1.037 to 128.9	0.047
SRQ-20	0.416	0.186	5.019	1.516	1.053 to 2.180	0.025

R²=0.497.

SRQ-20, Self-Reporting Questionnaire.

Our correlation analyses revealed that the participants' SRQ-20 scores were positively correlated with TST, SE and REM%, suggesting the significant impact of psychological factors on the participants' sleep duration, quality and structure. Given that the participants had been under stress for 2 months when this screening was performed, they had been exposed to its effects for a relatively long period of time, which suggested the possibility of chronic stress exposure. Therefore, individuals may exhibit restorative sleep compensation, along with increased sleep duration and REM sleep, which is consistent with the outcomes of previous investigations.¹⁷

Middle-aged and overweight men are reportedly considered to be at risk for OSAHS.²⁶ We also observed that the proportion of men was higher in the comorbid SAHS group, while the results of logistic regression analysis showed that men were more likely to have insomnia with comorbid SAHS. However, when considering sex as a covariate for further analysis, the results showed that the intergroup differences in ISI, SRQ, ODI, TS90% and MSpO₂ persisted, which suggests that sex may generate comorbid OSAHS in men with insomnia. However, the severity of SAHS and the degree of psychological distress were not affected by sex differences.

Wearable devices significantly improved the convenience of using sleep trackers, especially when we could continue to monitor the patients at their residence, which ensured that the monitoring environment was closer to natural sleep. However, research in China and globally on wearable sleep trackers is relatively limited. A study has shown that²⁷ compared with portable EEG, wearable sleep trackers had better sensitivity (92.1%) and accuracy (88.5%) when evaluating TST and SE but showed significant bias when determining sleep latency and sleep cycle. Hence, this approach has its limitations.

Limitations

This study has certain limitations. First, this was a cross-sectional observational study. Although wearable pulse oximeters can easily monitor participants' breathing during sleep, its clinical applications are considerably limited, and further testing is required to verify its reliability. Second, mental health screening was only performed using the ISI and SRQ, and a comprehensive psychological evaluation was not conducted on the participants' stress severity, anxiety, depression and other psychological conditions. Lastly, the small sample size of this study may have affected our screening results. Therefore, future studies should effectively record clinical symptoms and signs, improve the parameters for psychological and sleep questionnaires and confirm the diagnosis of suspected insomnia with comorbid SAHS using overnight polysomnography, thereby exploring the inherent connections of stress, insomnia and SAHS to a greater degree.

Implications

During crisis intervention, sedative-hypnotic drugs, such as benzodiazepines, have been widely used to alleviate

symptoms such as anxiety, tension and insomnia after stress and can rapidly improve clinical symptoms. Nevertheless, insomnia with comorbid SAHS has long been neglected in previous reports, and the use of benzodiazepines may worsen SAHS symptoms. Therefore, when assessing the situation during future emergency rescues, it is necessary to combine symptoms, signs and other clinical data to thoroughly screen insomnia patients with comorbid SAHS and avoid the adverse reactions caused by benzodiazepines.

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Contributors KZ participated in the design and data collection for the study and drafted the first version of the manuscript. CG and XW enrolled and clinically evaluated study subjects. CZ carried out the clinical diagnosis and critically reviewed the manuscript. ZW was responsible for drafting and revising the main contents of the paper. All authors read and approved the final manuscript.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The research protocol was approved by Institutional Review Board of Shanghai Mental Health Center (2020-10). This study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The subjects were assured of the following: their participation was voluntary, they could withdraw at any time without facing any negative consequences, their anonymity would be protected and the data obtained would not be used for purposes other than the present research. All participants provided their written informed consent. The research purpose and guarantee to protect the privacy of the subjects were explained verbally as well as in written form to the participants by the doctor.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The raw data required to reproduce these findings cannot be shared at this time as the data also forms part of an ongoing study.

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ORCID iD

Zhen Wang <http://orcid.org/0000-0003-4319-5314>

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Kaiming Zhuo obtained a master's degree from the Division of Psychosis at the Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine in 2014. He has been working at the Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine since 2005 where he is an attending psychiatrist. He has been to Inner Mongolia and Wuhan as a member of the national medical team for psychological rescue from 2019 to 2020. His main research interests include early psychosis and sleep.

Correction: Stress and sleep: a survey based on wearable sleep trackers among medical and nursing staff in Wuhan during the COVID-19 pandemic

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This article was previously published with an error in the text.

In the 'Statistical analysis' section under 'Data and methods', should read mean (SD) not $\chi(-)\pm s$.

In the 'Stepwise logistic regression' section under 'RESULTS', should read χ^2 not $\chi(-)^2$.

In table 3, the fourth column heading should read χ^2 not $\chi(-)^2$.



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