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REVIEW

Burden of Sleep Disturbance During COVID-19 Pandemic: A Systematic Review

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Abstract: Coronavirus disease 2019 (COVID-19) pandemic may exert adverse impacts on sleep among populations, which may raise awareness of the burden of sleep disturbance, and the demand of intervention strategies for different populations. We aimed to summarize the current evidence for the impacts of COVID-19 on sleep in patients with COVID-19, healthcare workers (HWs), and the general population. We searched PubMed and Embase for studies on the prevalence of sleep disturbance. Totally, 86 studies were included in the review, including 16 studies for COVID-19 patients, 34 studies for HWs, and 36 studies for the general population. The prevalence of sleep disturbance was 33.3%–84.7%, and 29.5–40% in hospitalized COVID-19 patients and discharged COVID-19 survivors, respectively. Physiologic and psychological traumatic effects of the infection may interact with environmental factors to increase the risk of sleep disturbance in COVID-19 patients. The prevalence of sleep disturbance was 18.4–84.7% in HWs, and the contributors mainly included high workloads and shift work, occupation-related factors, and psychological factors. The prevalence of sleep disturbance was 17.65–81% in the general population. Physiologic and social-psychological factors contributed to sleep disturbance of the general population during COVID-19 pandemic. In summary, the sleep disturbance was highly prevalent during COVID-19 pandemic. Specific health strategies should be implemented to tackle sleep disturbance.

Keywords: sleep disturbance, COVID-19 pandemic, SARS-CoV2

Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). COVID-19 outbreak, declared as a global pandemic by the World Health Organization (WHO) on March 11th 2020, has presented an unprecedented challenge to public health systems and caused global economic crises. The uncertainties and fears towards COVID-19, along with the societal consequences of mass lockdown, may lead to sleep disturbance and psychological burdens on a large number of individuals, including patients with COVID-19, healthcare workers (HWs), and the general public.

Sleep plays an essential role on regulation of psychological and physical processes.[1] Poor sleep and sleep disturbance could interact with psychological and physical disorders to worsen health consequences among populations. Several studies have reported impacts of COVID-19 on sleep in specific populations.[2–4] Sleep disorders may exert negative impacts on the process, prognosis, and rehabilitation of patients with COVID-19. Sleep disorders also affect the working ability

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of HWs. COVID-19-associated societal responses including home confinement, school suspension, and social isolation also increase the likelihood of sleep disturbance in the general public. However, risk factors for sleep disturbance and its associated health consequences still need to be addressed. Thus, we summarized the current evidence on the prevalence and associated factors of sleep disturbance in patients with COVID-19, HWs, and the general public. The increasing evidence addresses the necessity of awareness and interventions of sleep disturbance during and after COVID-19 pandemic.

Methods

Search Strategy

Electronic searches were performed in PubMed and Embase, and were updated on Dec 10th, 2020. The following terms were used for the searches, ie (sleep) OR (sleep disturbance) OR (sleep disorders) OR (sleep problems) OR (insomnia) OR (sleep apnea) OR (sleep breathing disorders) AND (COVID-19) OR (SARS-CoV2). The reference lists of full articles were also searched for relevant publications. The searches were conducted, and the full-text articles were reviewed and analyzed by 2 independent researchers (Lin YN and Li SQ). In case of disagreement between the two reviewers, a third reviewer (Liu ZR) reviewed the articles and consensus among the three reviewers was reached.

Study Selection

Studies were included if (1) the studies were cross-sectional, longitudinal, prospective, retrospective, or case-series in design; (2) the studies targeted populations including HWs, the general public, and COVID-19 patients; (3) the studies provided data of prevalence and/or risk factors of sleep disturbance; (4) the studies were written in English. Studies were excluded if (1) the full-text were unavailable; (2) studies were not written in English; (3) they were reviews, meta-analysis, conference abstracts, and protocols.

We initially identified 1430 studies. After removing 498 duplicates, we screened the remaining 932 studies by reviewing the titles and abstracts. Totally 136 studies were assessed for eligibility, and finally 86 studies were included in the review (Figure 1).

Assessment of Study Quality

Study quality was assessed using the Loney criteria through eight items including study design and sampling

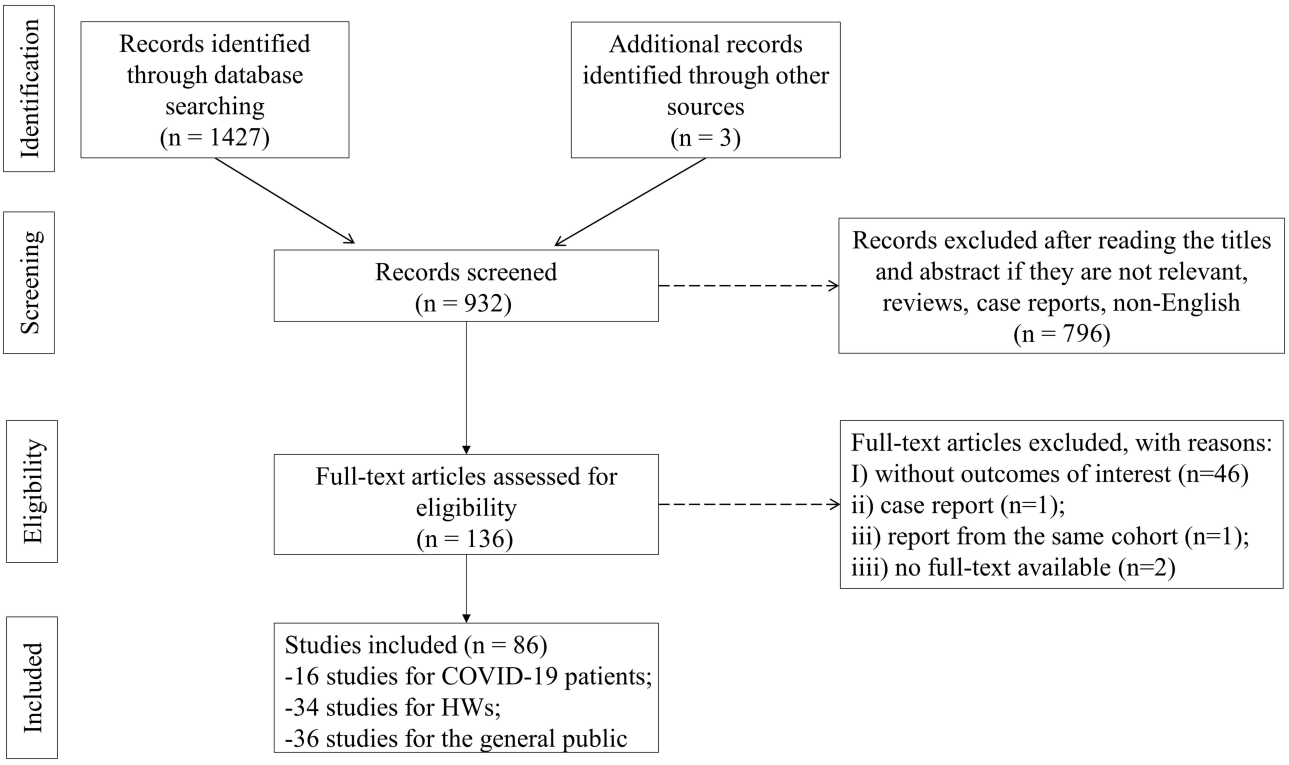

Figure 1 Flowchart of literature selection.

method, unbias sampling frame, sample size, appropriate measurement, unbiased measurement, response rate, estimates of prevalence, and description of study subjects.[5] Scores range from 0 to 8 points. A total score of 7–8 is considered as high quality, 4–6 as moderate quality, and 0–3 as low quality. The detailed quality assessment of the studies was shown in Table S1. Study quality was assessed independently by two researchers (Lin YN and Li SQ). In case of disagreement, a third reviewer (Liu ZR) reassessed the studies and consensus among the three reviewers was reached.

Results and Discussion

Sleep Disturbance in Patients with COVID-19

Hospitalized Patients

The prevalence of sleep disturbance (ranging from 33.3% to 84.7%) in hospitalized COVID-19 patients was reported in 6 studies[6–11] (Table 1). A retrospective study reviewed the psychiatric medical records of 329 COVID-19 patients, and showed 25.5% received psychiatric consultations, 33% of whom were diagnosed with sleep disorders (insomnia, early awakening, difficulty falling asleep), and 22.6% and 54.8% were prescribed benzodiazepines and non-benzodiazepine sedative-hypnotics (zolpidem), respectively.[10] In an Italian university hospital, 49.51% of 103 hospitalized COVID-19 patients complained of sleep disturbance without any sex difference. It should be noticed that symptoms of sleep disturbance appeared immediately after the admission, and the frequency increased from 36.36% on the first 2 days to 69.23% after 7-day hospitalization,[9] indicating that sleep disturbance in hospitalized COVID-19 patients cannot be simply explained by acute psychological response to the disease. Sleep disturbance was also found in mild patients even in mobile cabin hospitals, of whom more than two-thirds experienced insomnia on entry, but the overall insomnia levels (based on Insomnia Severity Index, ISI scores) were improved before discharge.[6]

Sleep disturbance may be associated with the adverse health consequences of COVID-19 patients. Compared to those without sleep disturbance, COVID-19 patients who suffered from sleep disturbance for at least 2 weeks during hospitalization presented with a slower recovery from lymphopenia, an increase in the deterioration of neutrophil-to-lymphocyte ratio. They also had a higher incidence of hospital-acquired infection, longer hospitalization, and an increased need for ICU care than those without sleep disturbance.[12] The findings indicated the negative impacts of a sustained period of sleep disturbance on the delay in recovery of immune dysfunction in COVID-19 patients.

Discharged Patients

Sleep disturbance continued to bother 29.5–40% of COVID-19 survivors during the early post-discharge period, as reported in 4 studies[13–15] (Table 2). Up to 29.5% of 370 Chinese survivors complained of sleep disturbance during a median time of 22 days after discharge.[13] A comparable proportion of 734 COVID-19 survivors (30.6%) from Bangali reported insomnia, disturbance in sound sleep, and nightmares,[16] while the prevalence (40%) was higher in an Italian study.[14] A French study showed that 30.8% of COVID-19 survivors still suffered from sleep disturbance even 110 days after being discharged, with no difference between ward- and ICU patients,[15] highlighting the need for a long-term follow-up for sleep and rehabilitation consultants.

Patients with Preexisting Sleep Disturbance

Preexisting sleep disturbance might increase the susceptibility of COVID-19.[17] A recent cross-sectional study showed that up to 60% of the patients reported sleep problems and had been taking sleeping pills over the past 12 months,[18] indicating a high rate of preexisting sleep problems in COVID-19 patients and a possible role of poor sleep on the susceptibility of COVID-19. Cruz and colleagues have proposed a hypothesis that dysregulation of circadian rhythm and sleep may be associated with increased risk of SARS-CoV-2 infection and the severity of its clinical manifestations.[17]

The preexisting obstructive sleep apnea (OSA) and obesity hypoventilation syndrome are common co-morbid diseases in COVID-19 patients. The prevalence of OSA in COVID-19 patients was reported in 6 studies[19–24] (Table 3). In severe COVID-19 patients, the prevalence of OSA reached 21–28.6%.[20,21] More recently, Perger and colleague conducted sleep tests in 44 COVID-19 patients, and identified 34% with OSA and 41% with central sleep apnea (CSA). Multivariate analysis revealed that higher BMI and higher obstructive AHI were associated with the need of ventilation support.[22] COVID-19 patients with OSA are 1.58 times more likely to develop critical illness.[23] The CORONADO study, which included 1317 hospitalized diabetic patients with COVID-19, also demonstrated that treated OSA prior to admission was associated with the

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Table 1 Characteristics of Studies Reporting the Prevalence of Sleep Disturbance in COVID-19 Patients

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Risk Factors	Quality Assessment Score
Zhang et al[6]	Feb 5, to Mar 6, 2020	China	A cross-sectional study	COVID-19 patients in mobile cabin hospitals (n = 30)	42.5	15/15	100	ISI, a semi-structured interview	≥8	73.3% (22 in 30)	NA	4
Hao et al[8]	Mar 18, to Mar 26, 2020	China	A cross-sectional study	Hospitalized COVID-19 patients (n=10), psychiatric patients (n=10), healthy controls (n=10)	37.4	6/4	NA	ISI, a semi-structured interview	≥8	50%	NA	4
Dai et al[7]	Feb 23, to Feb 26, 2020	China	A cross-sectional study	COVID-19 patients in Fangcang shelter hospital (n=307)	NA	174/133	NA	PSQI (Online)	≥6	84.7%	NA	4
Liguori et al[9]	Mar 30, to April 24 2020	Italy	A prospective study	Hospitalized COVID-19 patients (n = 103)	55	59/44	NA	Anamnestic interview	NA	49.51%	NA	4
Yue et al[10]	Jan 20, to Mar 8, 2020	China	A retrospective study	Hospitalized COVID-19 patients (n = 329)	49.78	171/158	NA	Review of electronic medical records	NA	25.5% of all patients received psychiatric consultations, 33.3% of whom were diagnosed with sleep disorders	NA	5
Iqbal et al[11]	2020	Qatar	A retrospective study	COVID-19 patients (n=50)	43.9	48/2	NA	Review of electronic medical records	NA	70% complained of sleep disturbance	NA	2

Abbreviations: ISI, Insomnia Severity Index; PSQI, Pittsburgh Sleep Quality Index.

Table 2 Characteristics of Studies Reporting the Prevalence of Sleep Disturbance in Post-Discharged COVID-19 Patients

Author	Study Period	Country	Design	Participants	Post-Discharge Period (Median or Mean, d)	Age (Mean, yrs)	Male/ Female (n)	Loss to Follow-up (%)	Screening Tools	Cut-off Values	Prevalence	Risk Factors	Quality Assessment Score
Wu et al[13]	NA	China	A case series	Post-discharged COVID-19 patients (n=370)	22	50.5	203/167	Loss to follow up (25.5)	PHQ-9	NA	29.5%	NA	3
Mazza et al[14]	Apr 6 to June 9, 2020	Italy	A cross-sectional study	Post-discharged COVID-19 patients (n=402)	31.29	57.80	265/137	NA	WHIIRS, an unstructured clinical interview	≥ 9	40%	NA	6
Akter et al[16]	Apr1 to June 30, 2020	Bangladesh	A cross-sectional study	Post-discharged COVID-19 patients (n=734)	28	NA	558/176	NA	A phone questionnaire	NA	Cannot sleep: 8.9%; Disturbance in sound sleep: 19.8%; Nightmare: 1.9%	NA	4
Garrigues et al[15]	NA	France	A cross-sectional study	Post-discharged COVID-19 patients (n=120)	110	63.2	75/45	Loss to follow up (24.7)	A phone questionnaire	NA	30.8%	NA	2

Abbreviations: PHQ-9, Patient Health Questionnaire-9; WHIIRS, Women's Health Initiative Insomnia Rating Scale.

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Table 3 Characteristics of Studies Reporting the Prevalence of Sleep Apnea in COVID-19 Patients

	Study Period	Country	Design	Participants	Age (Mean/ Median, yrs)	Male/ Female (n)	Prevalence of Sleep Apnea	Risk Factors	Quality Assessment Score
Kragholm et al[19]	The end of Feb, to May 16, 2020.	Denmark	A follow-up study	COVID-19 patients (n=4842)	57 for male, 52 for female	2281/ 2561	4% in male, 1.2% in female	NA	3
Bhatraju et al[20]	Feb 24 to Mar 9, 2020	United States	A case series study	Critically ill COVID-19 Patients (n=24)	64	15/9	21%	NA	2
Arentz et al[21]	Feb 20, to Mar 5, 2020	United States	A case series study	Critically ill COVID-19 Patients (n=21)	70	11/10	28.6%	NA	2
Perger et al[22]	April 8 to May 8th, 2020	Italy	A case series study	COVID-19 Patients (n=44)	AHI<5: 51, 5≤AHI<15: 62, 15≤AHI<30: 70; AHI≥30: 72	29/15	34% with OSA, 41% with central sleep apnea (CSA)	Higher obstructive AHI were associated with the need of ventilation	2
Gottlieb et al[23]	Mar 4, to June 21, 2020	United States	A retrospective cohort study	COVID-19 patients (n=8673)	41	4045/ 4625 (Not specified 2)	3.3% in all patients; 1.9% in non-hospitalized patients, 10.4% in hospitalized patients	OSA (OR = 1.58) was associated with the risk of critical illness.	3
Cariou et al[24]	Mar 10, to Mar 31, 2020	France	A follow-up study	Hospitalized COVID-19 patients with diabetes (n = 1317)	69.8	855/462	12.1% of patients with treated OSA	Treated OSA (adjusted OR = 2.8) was associated with the risk of death on day 7.	3

Abbreviations: AHI, Apnea Hypopnea Index; CSA, Central sleep apnea.

increased risk of death on day 7 (adjusted OR 2.65).[24] Thus, it is possible that OSA is not simply a co-morbidity, but could be a risk factor for poor outcomes in COVID-19 patients.[25,26] The plausible mechanistic pathways by which OSA may have adverse effects on OSA COVID-19 patients have been summarized in a previous review.[2]

Factors Associated with Sleep Disturbance in COVID-19 Patients

Physiologic Factors

Neuronal System Injury

The neuronal injury directly and indirectly caused by SARS-CoV-2 infection contributes to sleep disturbance in COVID-19 patients. SARS-CoV-2 could invade to the brain, possibly via the olfactory nerves or retrograde trans-synaptic dissemination from the lung to the medullary cardiorespiratory center.[27,28] SARS-CoV-2 then rapidly spread to specific brain areas including thalamus and brain stem, which play essential roles in sleep control and respiratory regulation, respectively, and thereby increase the risks of abnormal sleep-wake behaviors and SDB. SARS-CoV-2 is also capable of causing secondary neuronal injury due to aberrant innate immune response, leading to chronic neurological sequelae that adversely affect sleep, emotion regulation, pain sensitivity, and energy.[29,30] This indicates a possible long-lasting impact of COVID-19 on sleep. Additionally, the binding of SARS-CoV-2 to the ACE2-expressing endothelial cells together with hypercoagulation status may contribute to the increased risk of cerebrovascular events, which contribute to sleep disturbance including inversed sleep-wake cycle, sleep-disordered breathing (SDB), and increased paradoxical sleep.[31]

Symptoms, Severity of COVID-19, and Medication

Except for the neuronal pathology caused by the virus, the physical discomforts including cough, fever, pain, and dyspnea may also destroy sleep. Relief of symptoms help to improve sleep in COVID-19 patients. Jiang and colleagues showed that Pittsburgh Sleep Quality Index (PSQI) scores were associated with subjective perception of the disease severity in COVID-19 patients.[32] Yang and colleagues recently found that scores of PSQI were positively associated with severity of pneumonia, and improvement of PSQI scores were positively related to improvement from COVID-19.[33] To be noted, adverse effects of medication, eg the use of corticosteroids, sedatives, beta-blocker, and nonsteroidal anti-inflammatory drugs (NSAID) also create and exacerbate sleep problems in COVID-19 patients. Appropriate timing of medication, also called chronotherapy, should be taken into consideration to better fit patients' circadian rhythms and to minimize the side effects of medication on sleep eg. the use of corticosteroids, sedatives, beta-blocker, and nonsteroidal anti-inflammatory drugs (NSAID) also create and exacerbate sleep problems in COVID-19 patients. Appropriate timing of medication, also called chronotherapy, should be taken into consideration to better fit patients' circadian rhythms and to minimize the side effects of medication on sleep.[34]

Psychological Factors

Sleep disturbance could also occur as the result of the psychologically traumatic effects of COVID-19. Two-week psychological intervention was able to improve PSQI scores, indicating a relationship between sleep disturbance and mental health in COVID-19 patients.[33] Studies have demonstrated a high prevalence of mental health disorders in hospitalized and discharged patients with COVID-19 due to the fear of the new fatal virus infection, uncertainty about disease progression, worries about physical disability, loneliness and social isolation.[8,10,13] Sleep is usually reciprocally associated with mental health. Sleep disturbance, and mental health disorders like depression, anxiety, and PTSD not only share symptoms, but also form a vicious cycle to deteriorate the prognosis in patients with COVID-19.Post-traumatic stress disorder (PTSD) not only share symptoms, but also form a vicious cycle to deteriorate the prognosis in patients with COVID-19.

Environmental Factors

Environmental factors including noise, abnormal light exposure, patient care activities, diagnostic and treatment procedures contribute to the ICU-related sleep disturbance. A previous study has indicated an innegligible role of environmental factors on sleep disturbance in hospitalized patients with COVID-19,[12] particularly for those critically ill patients. Sleep disturbance occurs frequently in ICU patients, presenting with decreased sleep efficiency, a shift toward light stages of sleep, increased arousals, and abnormal circadian rhythmicity.[35]

Taken together, physiologic and psychological traumatic effects of the infection may interact with environmental factors to increase the risk of sleep disturbance in COVID-19 patients. However, several questions remain to be solved. How does sleep change during the acute infection of COVID-19 and what is the patho-physiological mechanism? What is the relationship between sleep disturbance and occurrence and prognosis of COVID-19? Does sleep interference improve the prognosis of COVID-19? Moreover, yet little is known about long-term impacts of COVID-19 on sleep. A recent meta-analysis demonstrated a decrease in the frequency of

insomnia from 41.9% (95% CI, 22.5–50.5) during the acute illness to 12.1% (95% CI, 8.6–16.3) after a follow-up duration varying from 60 days to 12 years in patients admitted to hospital for SARS or MERS.[36] In the case of COVID-19, further studies are warranted to illustrate how long sleep disturbance would last after rehabilitation, and to what extent sleep disturbance could be improved over time.

Sleep Disturbance in Healthcare Workers

A total of 34 studies were included, with the subjective sleep quality being assessed by using self-reported questionnaires[4,37–69] (Table 4). The prevalence of poor sleep quality in HWs during COVID-19 pandemic ranged from 18.4% to 84.7% based on scores of PSQI,[4,37–47] which were comparable to that before the pandemic.[70] A longitudinal study showed worsened sleep quality in 116 doctors and 99 nurses after one-month during the early COVID-19 outbreak, with a percentage of HWs with PSQI > 5 increasing from 61.9% to 69.3%.[44] The prevalence of sleep disturbance in HWs was generally higher than that in non-HWs or general population.[53–55] Insomnia is the most prominent symptom with a prevalence ranging from 23.6% to 68.3% based on ISI scores.[48–55,57,59–62] Moderate-to-severe insomnia with ISI≥15 presented in 6.78%-15%.[48,50–52,54,55,57,59,61,62] Another two studies used AIS at a cut-off value of 6 showed 52.8% of nurses,[65] and 68.3% of physicians[66] suffered from insomnia.

Except for insomnia, symptoms of parasomnias including nightmares, sleepwalking, sleep terrors are more frequently reported in HWs than non-HWs.[43] Notably, Zhuo and colleagues carried out a study to investigate overnight sleep in 26 HW with insomnia using medical ring-shaped pulse oximeters, and showed that the incidence of comorbid moderate to severe sleep apnea in insomnia HW reached 38.5%, indicating a high comorbidity rate of sleep apnea and insomnia attributable to stress.HWs with insomnia using medical ring-shaped pulse oximeters, and showed that the incidence of comorbid moderate to severe sleep apnea in insomnia HWs reached 38.5%, indicating a high comorbidity rate of sleep apnea and insomnia attributable to stress.[71]

Factors Linked to Sleep Disturbance of HWs

High Workloads

High daily workloads contribute to poor sleep in HWs. Increased working hours were associated higher risk of sleep disturbance.[53,58] The intensity of physical activity during daily work was negatively associated with sleep duration, and was positively associated with the feeling of tiredness during the wake-up in the morning.[72]

Being a shift worker has been reported to have 3.48 times likelihood to experience insomnia in the battle against COVID-19.[43] Irregular and prolonged work shifts disrupt homeostatic and circadian rhythms and cause disturbance of several hormones, including melatonin and cortisol, leading to insufficient or inadequate sleep. Shift work not only impairs daytime function, and increases the risk of critical errors in HWs at work,[73] but may also make HWs themselves more prone to COVID-19 infection.[74,75] A recent single-center, retrospective study showed that implementation of new night shift schedule, changing from a four-day cycle to only daytime work for doctors with emergency techniques and extensive first aid experience and a six-day cycle in other doctors and nurses, significantly decreased the mortality of critically ill patients with COVID-19.[76] Thus, more reasonable shift working schedules that allow for adequate rest for HWs and at the same time, ensure the continuity of treatments for patients, should be highly recommended during COVID-19 emergency status.[76,77]

Occupation-Related Factors

Several occupation-related factors contribute to the increased risk of sleep disturbance in HWs. The frontline HWs who are engaged in direct diagnosis, treatment, and care of COVID-19 patients,[41,45,46,48–52,54,60,63,65,66] were more likely to experience sleep disturbance. Being a nurse is a risk factor for sleep disturbance (OR:1.48 to 3.132),[41,46,62] while being a doctor was 0.44 times less likely to develop insomnia.[49] The results were consistent with a previous study showing lower scores on posttraumatic stress in doctors than in nurse during SARS outbreak.[78] However, being consultants and physicians, who took more responsibility on treating COVID-19 patients, were associated with sleep disturbance.[4,47] The differences may be due to the fact that nurses are more likely to have more intense workloads, more frequent shift works, and more direct contacts with COVID-19 patients than doctors.[49] Education and working experience are also closely associated with sleep problems in HWs. HWs with lower education level,[49] less work experience,[50,66] and poorer knowledge of crisis response,[41] and who were lack of sufficient protective equipment[57] had higher probability of experiencing sleep problems.

Psychological Factors

Psychological factors were associated with sleep disturbance in HWs, including psychological symptoms (ie depression and anxiety),[29,37–39,44,45,58,66] COVID-19-related bereavement,[45,64] worries about the COVID-19 outbreak,[49,65] being worried about being infected,[49]

Table 4 Characteristics of Studies Reporting the Prevalence of Sleep Disturbance in HWs

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Wang et al[37]	Jan 30, to Feb 7, 2020	China	A cross-sectional study	HWs (n=123)	33.75	22/111	NA	PSQI	>7	38%	Being an only child (OR = 3.4), exposure to COVID-19 patients (OR = 2.97), and depression (OR = 2.83)	4
Tu et al[38]	Feb 7, to 25, 2020	China	A cross-sectional study	Frontline nurse (n=100)	34.44	0/100	100	PSQI	≥7	60%	Depression symptoms (OR = 3.16)	6
Cheng et al[39]	Feb 9 to 13, 2020	China	A cross-sectional study	Pediatric HWs (n=534)	NA	94/440	NA	PSQI	>7	30%	PSQI scores positively correlated with the anxiety.	4
Qi et al[40]	Feb 2020	China	A cross-sectional study	FHWs (n=801), NFHWs (n=505)	33.1	256/1050	NA	PSQI; AIS	>6	71.7% (78.4% for FHWs and 61.0% for NFHWs)	NA	4
Zhou et al[41]	Feb 21 to 23, 2020	China	A cross-sectional study	FHWs (n= 1931)	35.08	88/1843	NA	PSQI	≥7	18.4%	Older age (OR=1.043), being nurse (OR=3.132), being working in outer emergency medical team (OR=1.755), being familiar with crisis response knowledge (OR=0.70)	5
Wu et al[42]	NA	China	A cross-sectional study	HWs at the designated hospital (n=60), HWs at the non-designated hospital (n=60)	33.5	31/89	NA	PSQI	>7	100% in HWs at the designated hospital	NA	3

(*Continued*)

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Table 4 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Herrero San Martin et al[43]	Mar 1 to Apr 30, 2020	Spain	A cross-sectional study	HWs (n=100), non-HWs (n=70)	36.4	70/100	85%	PSQI, ISI	PSQI:≥7; ISI:>8	64% in HWs with PSQI ≥7; 44% with ISI>8; 58% with parasomnias	Being a shift worker (OR = 3.48).	4
Zhao et al[44]	First survey: Jan 18, 2020; Second survey: Feb 18, 2020	China	A longitudinal study	Doctors (n=116), Nurses (n=99)	Doctors: 37.39; nurses: 34.44	Doctors: 47/69; nurses: 4/95	95.83%	PSQI	>5	Increasing from 61.9% to 69.3% after one-month follow-up	Longer work times handling febrile patients, more years of work experience, and the use of online CBT were associated with lower PSQI scores. Subjective psychological stress related to COVID-19 was positively correlated with changes in total PSQI scores.	4
Wang et al[45]	Mar 4 to 9, 2020	China	A cross-sectional study	HWs (n=1514), non-HWs (n=487)	HWs:31; non-HWs:33	HWs: 193/294; non-HWs: 517/997	98.6%	PSQI	>5	66.1%	Being NFHWs (OR = 2.07), being FHWs (OR = 2.33), burden of caring for the elderly or children (OR = 1.47), COVID-related bereavement (OR = 1.91), anxiety (OR = 2.98), and depression (OR = 2.96).	6
Alnofaiey et al[4]	May to Aug 2020	Saudi Arabia	A cross-sectional study	Physicians (n=462)	NA	227/235	NA	PSQI	>5	43.9%	Doctors aged 31–40 yrs, associate consultants and residents had higher prevalence of sleep disorders.	5

Jahrami et al[46]	Apr 2020	Kingdom of Bahrain	A cross-sectional study	FHWs (n=129), NFHWs (n=128)	40.2	77/180	94%	PSQI	≥5	75.2%	Risk factors for combined poor sleep quality and moderate-severe stress: Being female sex (OR = 2.03). Protective factors for combined poor sleep quality and moderate-severe stress: professional background (OR = 0.7).	5
Giardinoet al[47]	June 5 to 25, 2020	Argentina	A cross-sectional study	HWs (n=1059)	41.7	287/770 (Non Binary: 2)	NA	PSQI; ISI; SWIFT	PSQI:≥5; ISI: ≥8; SWIFT (> 12 for young adults; > 9 for middle-aged adults)	84.7% with PSQI≥5, and 73.7% with ISI≥8; 21.7% with fatigue/ wakefulness problems.	Living with adults >10 (OR=1.63 for ISI), working in private sector (OR=1.56 for ISI), being physician (OR=4.87), contact with COVID-19 patients (OR=3.11 for ISI), sleep medication before lockdown (OR=92.0 for PSQI, OR=5.67 for ISI), sleep medication during lockdown (OR=67.0 for PSQI, OR=7.8 for ISI), gender (OR=6.4 for PSQI, OR=4.31 for ISI),	4

(*Continued*)

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Table 4 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Cai et al[48]	First survey (Peak period): Jan 29 to Feb 2, 2020; Second survey (Stable period): Feb 26 to Feb 28, 2020	China	A longitudinal study	Nurses (First survey, n=709; second survey, n=621)	NA	Peak period:25/684; Stable period:16/605	NA	ISI	≥8	38.5% during outbreak, and 39.9% during stable period	Fangcang shelter hospitals (OR=3.520), physical condition change worse (OR=1.445)	4
Zhang et al[49]	29 Jan to Feb 3, 2020	China	A cross-sectional survey	HWs (n=1563)	NA	492/1071	NA	ISI	≥8	36.1%	An education level of high school or below (OR = 2.69), currently working in an isolation unit (OR = 1.71), being worried about being infected (OR = 2.30), perceived lack of psychological support from news or social media (OR = 2.10), and being uncertain about effective disease control (OR = 3.30), being a doctor (OR = 0.44)	5

Wang et al[50]	Feb 2 to 3, 2020	China	A cross-sectional study	High-risk HWs (n=401), low-risk HWs (n=644)	NA	148/897	80.1% from the fever clinic, emergency department, ICU, and infectious disease departments, and 70.3% from the wards/ auxiliary departments	ISI	≥8	49.9%	High-risk HW (OR = 1.6), less work experience (OR = 1.88).	6
Lai et al[51]	Jan 29 to Feb 3, 2020	China	A cross-sectional study	HWs (n=1257)	NA	293/964	68.7%	ISI	≥8	34.0%	Working in the frontline (OR=2.97)	6
Que et al[52]	Feb 16 to 23, 2020	China	A cross-sectional study	HWs (n=2285)	31.06	707/1578	NA	ISI	≥8	28.75%	Drinking (OR=2.43), attention to negative information about the pandemic (OR=3.34), receiving negative feedback from families or friends who joined front-line work (OR=3.47), joining front-line work (OR=1.90) and unwilling to join front-line work if given a free choice (OR=3.39).	6
Zhou et al[53]	Feb 14 to Mar 29, 2020.	China	A cross-sectional study	FHWs (n=606), general population (n=1099)	FHW: 35.77; general population:29.23	FHWs: 114/ 492; general population:336/ 763	NA	ISI	≥8	32.0%	Daily working hours (OR=1.60), BMI (OR=1.06)	6

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Table 4 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Zhang et al[54]	Feb 19 to Mar 6, 2020	China	A cross-sectional study	HWs (n = 927), non-HWs (n = 1255)	NA	HWs: 249/678; non-HWs:532/723	NA	ISI	>8	38.4%	Living in rural areas (OR= 2.18), being at risk of contact with COVID-19 patients in hospitals (OR, 2.53), having organic diseases (OR, 3.39)	6
Liang et al[55]	Feb 14 to Mar 29, 2020	China	A cross-sectional study	FHWs (n=899), general population (n=1104)	NA	FHWs: 168/731; general population:337/767	NA	ISI	≥8	57.97% for FHWs in Hubei Province; 40.34% for FHW in other regions	NA	6
Zhang et al[56]	June 6 to 13, 2020	China	A cross-sectional study	HWs (n=642)	NA	96/546	NA	ISI	≥8	95.52% for HWs with probable PTSD, 40.16% for the non-PTSD	NA	6
Florin et al[57]	Apr 10 to 19, 2020	France	A cross-sectional study	Radiologists (n=1515)	NA	844/671	21%	ISI	≥8	40.9%	The lack of sufficient protective equipment (OR= 1.7), increase of teleradiology activity (R=1.5), negative impact on education (OR=2.5), living with another HWs (OR=0.6), working in a public hospital (OR= 0.4)	6

Jain et al[58]	May 12 to 22, 2020	India	A cross-sectional study	Anaesthesiologists (n = 512)	NA	285/227	NA	ISI	≥8	60.5%	Being 41–45 yrs (OR=2.641), unmarried (OR=1.184), being stress to COVID-19 (OR=2.014), increasing working hours (OR=3.157), GAD score ≥5 (OR=10.499), being 45–50 yrs (OR=0.506), being >50 yrs (OR=0.797), being male (OR=0.758), being consultant (OR=0.504)	6
Almater et al[59]	Mar 28 to Apr 4, 2020	Saudi Arabia	A cross-sectional study	ophthalmology physicians (n=107)	32.9	60/47	30.6%	ISI	≥8	44.9%	NA	5
Cai et al[60]	Feb 11 to 26, 2020	China	A case-control study	FHWs (n=1173), NFHWs (n=1173)	FHWs:30.6; NFHWs:30.5	FHWs:354/819; NFHWs:348/825	NA	ISI	>9	47.8% for FHWs, 29.1% for NFHWs	Working in the frontline (OR=1.96)	6
Khanal et al[61]	Apr 26 to May 12, 2020	Nepal	A cross-sectional study	HWs (n=475)	28.2	225/250	NA	ISI	≥10	33.9%	Stigma experience (OR=2.37), history of medication for mental health problems (OR=3.82), Janajati ethnic group (OR=1.74), less than 5 years' work experience (OR=0.50)	5
Şahin et al[62]	Apr 23 to May 23, 2020	Turkey	A cross-sectional study	HWs (n=939)	NA	319/620	NA	ISI	≥10	50.4%	Female (OR=1.48), a history of psychiatric illness (OR=2.37), taking the COVID-19 test (OR=1.45)	6

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Table 4 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Alshekaili et al[63]	Apr 8 to 17, 2020	Oman	A cross-sectional study	FHWs (n=574), NFHWs (n=565)	FHWs:35.8; NFHWs:36.9	FHWs:102/472; NFHWs:126/439	NA	ISI	≥14	18.5%	FHWs was 1.5 times more likely to have insomnia than NFHWs.	6
Rossi et al[64]	Mar 27 to 31, 2020	Italy	A cross-sectional study	HWs (n=1379)	39.0	315/1064	NA	ISI	≥22	8.27%	Being nurses (OR=2.03) and health care assistants (OR=2.34), having a colleague deceased (OR=2.94)	6
Zhan et al[65]	Mar 3 to 10, 2020	China	A cross-sectional study	Nurse (n=1794)	NA	54/1740	NA	AIS	≥6	52.8%	Being female (β=0.04), more working experience (β=0.113), chronic diseases (β=−0.046), midday nap duration (β=−0.082), frequency of night shifts (β=−0.049), direct participation in the rescue of patients with COVID-19 (β=−0.112), negative experiences (β=−0.061), the degree of fear of COVID-19 (β=0.179), perceived stress (β=0.16), fatigue (β=0.379), professional psychological assistance (β=0.063).	6

Abdulah et al[66]	Apr 9 to 24, 2020	Iraqi	A cross-sectional study	Physicians (n=268)	35.06	188/80	NA	AIS	≥6	68.3%	AIS score was positively associated with stress, and the duration of dealing with suspected/ confirmed cases of COVID-19, and was negatively associated with age and experience.	5
Mosheva et al[67]	Mar 19 to 22, 2020	Israel	A cross-sectional study	Physician (n=1106)	46.07	564/542	NA	An inventory of pandemic related stress factors	/	22.1%	Sleep difficulties was associated with anxiety.	3
Sharif et al[68]	NA	52 countries	A cross-sectional study	Neurosurgeons (n=357)	NA	NA		Self-Reporting Questionnaire-20 Items	/	24.8% reported "slept badly".	NA	4
Bhargava et al[69]	Apr 1 to 20, 2020	7 countries	A cross-sectional study	Dermatologists (n=733)	NA	NA	NA	Self-designed questionnaires	/	30% with insomnia	NA	4

Abbreviations: HWs, healthcare workers; FHWs, frontline healthcare workers; NFHWs, non-frontline healthcare workers; PSQI, Pittsburgh Sleep Quality Index; ISI, Insomnia Severity Index; AIS, Athens Insomnia Scale; ESS, Epworth Sleepiness Scale.

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perceived lack of psychological support,[49] and preexisting psychological diseases or sleep medication.[47,61,62] The relationship between sleep disturbance and COVID-19-related stress may be bidirectional. On one hand, the stress associated with high risk of the virus infection and high patient mortality, perceived physical isolation, the necessity for constant vigilance regarding infection control procedures, and concern about family members could cause anxiety, and depression,[46] and impair sleep quality. On the other hand, poor sleep may result in daytime fatigue, loss of interest, impairment of the daytime function, and increase the risk of critical errors at work,[73] which in turn, worsens psychological condition in HWs.

Moreover, other factors including being female,[62,65] being aged 41–45 yrs,[58] being the only child,[37] having burden of caring for the elderly or children,[45] physical condition and medication history,[45,47,48,61,62] being unmarried,[58] also contribute to sleep disturbance in HWs.

Taken together, high workloads may interact with COVID-19-related stress to increase the risk of sleep disturbance in HWs. The majority of the included studies were cross-sectional surveys showing the prevalence of sleep disturbance in HWs during the pandemic. Only one longitudinal study reported a slight increase in the prevalence of sleep disturbance.[44] Further studies should be conducted to determine the prevalence of new-onset or worsened sleep disturbance during the pandemic. Additionally, the impacts of sleep disturbance on health being, life quality and working performance in HWs during and after the pandemic also need further investigation.

Sleep Disturbance in the General Public

The prevalence of sleep disturbance in the general population during COVID-19 pandemic was reported in 36 studies,[79–114] ranging from 17.65% to 81%,[79–86] 24.66% to 86%,[87–89–93–95–96] and 30% to 56%,[100–103] based on scores of PSQI, ISI and AIS, respectively (Table 5), which were generally higher than that before the pandemic.[83,115] However, the effects of COVID-19-related lockdown on the public sleep quality remain controversial. Data from Italian and Australian studies reported that approximately half of the participants experienced worsened sleep quality during the lockdown.[84,85,107,108] Similarly, a study in China showed more than one-third of the participants had increased impaired sleep quality.[91] Symptoms of sleep disturbance commonly overlapped with those of depression, anxiety and PTSD in the general public.[83] On the contrary, a longitudinal study in the United State showed that 47% had improved sleep with longer sleep duration, and only 29% had worsened sleep from baseline to lockdown.[116] Another multicenter study from 11 countries also showed a reduced prevalence of insomnia after 2-month lockdown.[110] The results may indicate societal resilience to the chronic threat of viral infection and the changes of daily life. The varied proportions of sleep disturbance and its changes among the countries may be, at least partially, explained by the difference in epidemic control policy and the public attitude towards COVID-19 crisis. Interestingly, Kocevska and colleagues found that 20% of pre-pandemic good sleepers experienced worsened sleep, while a quarter of participants with pre-pandemic clinical insomnia experienced an amelioration of insomnia during COVID-19 pandemic.-[117] They argued that the effects of lockdown on sleep quality is not uniform, and emphasized the individual difference in response to COVID-19 crisis.

Factors Linked to Sleep Disturbance of General Public

Physiologic Factors

The circadian rhythm may be altered due to reduced exposure to sunlight, reduced physical activity and changes in working schedule during COVID-19 lockdown. However, the impacts of circadian rhythm alteration on sleep and other health consequences are controversial. On one hand, reduced social jetlag (driven by delayed mid-sleep on weekdays), reduced social sleep restriction (driven by increased sleep duration on weekdays) and decreased sleep debt may harmonize sleep schedules throughout the week, and thereby may limit the decline in sleep quality during the lockdown.[118,119] On the other hand, later chronotype, manifested as delayed mid-sleep on weekdays, may be associated with increased risk of mood symptoms including depression,[120] which in turn, may worsen sleep quality.

Social-Psychological Factors

The impacts of age on sleep during COVID-19 pandemic seem controversial. Two studies revealed that people aged more than 30 yrs are more likely to develop sleep disturbance during COVID-19 pandemic,[88,106] consistent with previous studies showing that the prevalence increased with age.[121,122] The age-related deterioration in sleep may be attributable to not only the effects of aging on circadian pacemaker and sleep structure but also the increased working and social stress that older people

Table 5 Characteristics of Studies Reporting the Prevalence of Sleep Disturbance in the General Public

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Wang et al[79]	Feb 4 to 8, 2020	China	A cross-sectional study	n = 6437	31.40	2824/3613	79%	PSQI	>7	17.65%	being older (OR = 1.42), being female (OR = 1.35), poor self-reported health status (OR = 5.59), believing COVID-19 had caused a high number of deaths (OR = 1.73), believing COVID-19 was not easy to cure (OR = 1.34), and regular exercise (OR = 0.77)	7
Huang et al[80]	Feb 3 to 17, 2020	China	A cross-sectional study	n = 7236	35.3	3284/3952	NA	PSQI	>7	18.2%	being healthcare workers (OR = 1.32)	6
Guo et al[81]	Feb 1 to 10, 2020	China	A cross-sectional study	n = 2441	NA	1162/1279	NA	PSQI	>7	20.6%	Direct exposure to COVID-19 (OR = 1.70), perceived impact on livelihood (Relatively large, OR = 1.32; very large, OR = 1.25), emotion-focused coping (OR = 1.12).	6
Zhao et al[82]	February 18 to 25, 2020	China	A cross-sectional study	n = 1630	29.17	NA	NA	PSQI	>5	36.38%	Anxiety mediated the relationship between perceived stress and sleep quality.	6

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Table 5 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Casagrande et al[83]	Mar 18 to Apr 2, 2020	Italy	A cross-sectional study	n = 2291	30.0	580/1708; Other:3	NA	PSQI	>5	57.1%	Being female (OR= 1.75), being unemployed (OR= 1.34), living in North Italy (OR= 1.24), being uncertain regarding COVID-19 exposure (OR= 1.21), knowing people that died because of COVID-19 (OR= 1.62).	6
Cellini et al[84]	Mar 24 to 28, 2020	Italy	A cross-sectional study	n = 1310	23.91	430/880	NA	PSQI	>5	Increased from 40.5% pre-lockdown to 52.4% post-lockdown	Poor sleep quality was associated with subjective elongation of time (r = 0.33), and the increased use of digital media (r = 0.15).	6
Barrea et al[85]	Jan to Apr 30, 2020	Italy	A retrospective study	n = 121	44.9	43/78	NA	PSQI	≥5	Increased from 50.4% pre-quarantine to 81% post-quarantine	NA	6
Bigalke et al.[86]	Apr 25 to May 18, 2020	United States	A cross-sectional study	n = 103	38	42/61	NA	PSQI; ISI	PSQI: >5; ISI: >7	66% with a PSQI score >5; 47.6% with ISI > 7;	Higher COVID-19 related anxiety was associated with higher ISI	6
Killgore et al[87]	Apr 9 to 10, 2020	United States	A cross-sectional study	n = 1013	NA	466/567	NA	ISI	≥8	56%	Worries over COVID-19 were correlated with insomnia (r = 0.37); Insomnia severity was associated with elevated suicidal ideation (r = 0.31).	5

Wang et al[88]	Feb 10 to 17, 2020	China	A cross-sectional study	n = 19,372	NA	9307/10,065	82.4%	ISI	≥15	13.3%	Living in Hubei Province (OR = 2.376), no outside activity for 2 weeks (OR = 1.927), and age 35–49 years (OR = 1.262)	7
Yu et al[89]	Apr 6 to 20, 2020	China	A cross-sectional study	n = 1138	NA	391/747	NA	ISI; Questions on sleep quality, sleep initiation, and sleep duration; Brief Insomnia Questionnaire (BIQ)	≥10	29.9%	Insufficient store of masks (OR = 1.96), perceived high level of stress (OR=2.10), daily life interfered by COVID-19 (OR=1.55), tertiary education (OR=0.66)	7

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Table 5 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Shi et al[90]	Feb 28 to Mar 11, 2020	China	A cross-sectional study	n = 56,679	35.97	27,149/ 29,530	79.9%	ISI	≥8	29.2%	Being with confirmed or suspected COVID-19 (OR = 3.06), family members or friends of patients with COVID-19 (OR=1.62), potential occupational exposure risks to COVID-19 (OR = 1.60), being a close contact of a COVID-19 patient (OR=1.55), centralized quarantine or home quarantine experience (OR=1.63), Hubei resident (OR=1.2), being frontline workers (OR=1.06), being male (OR = 1.13), younger than 40 yrs (OR = 1.07), lower income (OR =1.10), history of chronic diseases (OR=1.53), history of psychiatric diseases (OR 1.70), being at work (OR = 0.87), being married (OR=0.76)	8

Li et al[91]	Feb 5 to 19, 2020	China	A cross-sectional study	n = 3637	34.46	1346/2291	NA	ISI	>7	Increased from 26.2% before COVID-19 outbreak to 33.7% during COVID-19 outbreak; 13.6% developed new-onset insomnia; 12.5% had worsened insomnia symptoms	Being female (OR = 1.52), mental illness (OR = 1.63), COVID-19–related stress (OR = 1.40), increased severity of anxiety (OR = 1.15), and depressive symptoms (OR = 1.28) and prolonged time in bed (>60 minutes, OR = 1.30) during the outbreak.	5
Huang et al[93]	Feb 14 to Mar 29, 2020	China	A cross-sectional study	n=1172	28.39	360/812	NA	ISI	≥8	24.66%	NA	6
Ren et al.[94]	Feb 14 to Mar 29, 2020	China	A cross-sectional study	n = 1172	22.0	360/812	NA	ISI	≥15	7.2%	NA	6
Gualano et al[92]	Apr 19 to May 3, 2020	Italy	A cross-sectional study	n = 1515	42	511/973	NA	ISI	≥8	33%	Being females (OR = 1.70), being with chronic conditions (OR = 1.67)	6
Bartoszek et al[95]	Two weeks after Apr 3 2020)	Poland	A cross-sectional study	n = 471	25.5	68/403	NA	ISI	>7	86%	NA	6
Marroquín et al[96]	Mar 26 to 28, 2020	United States	A cross-sectional study	n = 435	39.2	230/202; Other:3	NA	ISI	≥10	38.6%	Being under a stay-at-home order was associated with higher depression, GAD symptoms, insomnia.	6

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Table 5 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Kokou-Kpolou et al[97]	May 3 to 16, 2020	France	A cross-sectional study	n = 556	30.06	136/420	NA	ISI	≥15	19.1%	Being with undergraduate levels (OR = 2.59), those attending college (OR = 2.41), worries about the COVID-19 (OR = 1.39), pre-existing mental health illness (OR = 1.22).	5
Rossi et al[98]	Mar 27 to Apr 6, 2020	Italy	A cross-sectional study	n = 18,147	38.0	3653/14,207	NA	ISI	≥22	7.3%	Being female (OR = 1.50), living in South Italy (OR = 1.41), having experienced a stressful life event due to COVID-19 (OR = 1.58), discontinued working activity (OR = 1.22), loved one being deceased (OR = 1.74), lower education (OR = 1.76), being homemakers (OR = 1.39), being unemployed (OR = 1.33), childhood trauma (OR =1.50), prior psychiatric disorders (OR = 1.76)	6

Salfi et al[99]	First survey: Mar 25 to 31, 2020; second survey: Apr 21 to 27, 2020	Italy	A longitudinal study	First survey: n =7107; second survey: n=2701	First survey: 32.37; second survey: 32.37	First survey: 1616/5491; second survey: 491/2210	NA	ISI	>14	For females: decreased from 13.12% pre-lockdown to 11.63% post-lockdown; For males: increased from 9.37% pre-lockdown to 12.02% post-lockdown	NA	6
Fu et al[100]	Feb 18 to 28, 2020	China	A cross-sectional study	n = 1242	NA	376/866	NA	AIS	≥5	30.0%	Being female (OR = 1.36), bachelor's degree and above (OR = 1.40), having high monthly income (CYN) (1000–5000, OR = 2.61; >5000, OR = 2.14), with no physical exercise (OR = 1.85)	6
Voitsidis et al[101]	Apr 10 to 13, 2020	Greece	A cross-sectional study	n = 2363	NA	563/1800	NA	AIS	NA	37.6%	predicted insomnia was equal to 3.232 + 0.398 (JGLS) + 1.338 (PHQ-2) + 0.63 (IUS) + 0.178 (COVID-19 worry)	5
Parlapani et al[103]	NA	Greece	A cross-sectional study	n = 103	69.85	40/63	NA	AIS	≥10	37.9%	NA	5
Janati Idrissi et al[102]	Apr 1, to May 1, 2020	Morocco	A cross-sectional study	n = 827	35.9	395/432	NA	AIS, ESS	AIS≥6, ESS≥11	56.0% with insomnia and 9.9% with daytime sleepiness	Living in urban areas (OR = 2.09), having chronic diseases (OR = 2.14)	6

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Table 5 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Li et al[104]	Apr 10 to 23, 2020	China	A cross-sectional study	n = 1970	37.81	650/1305; transgender: 15	NA	5-point Likert scale questionnaire	>0	55.8%	Worry about COVID-19 (OR = 1.04), academic/occupational interference by COVID-19 (OR = 1.12), impact of COVID-19 on social interaction (OR = 1.07), perceived social support (OR = 0.91), specific support against COVID-19 (OR = 0.92), self-reported physical health (OR = 0.80)	5
Léger et al[105]	Apr 15 to 17, 2020	France	A cross-sectional study	n = 1005	NA	NA	NA	items of the French Health Barometer	NA	73%	Risk factors for sleep problems with daytime impairment and/or sleeping drug use: being female (OR = 1.66), being unemployed before the lockdown (OR = 1.50), having financial difficulties due to the lockdown (OR = 1.85), exposure to media and screens (OR = 1.39).	3

Ara et al[106]	May 12, 18, 2020	Bangladesh	A cross-sectional study	n = 1128	NA	622/506	NA	A self-reporting questionnaire	NA	33.24%	Aged 31–40 years (OR = 4.04), being female (OR = 1.56), working from home or taking online classes (OR = 1.34), losing a job (OR = 2.41), perception regarding the risk of getting infected (OR = 1.45), anxiety (OR = 1.42), and sleeping more at daytime (OR = 1.86).	4
Stanton et al[107]	Apr 9 to 19, 2020	Australia	A cross-sectional study	n = 1491	50.5	484/999	NA	A self-reporting questionnaire	NA	40.7% with negative changes, 8.6% with positive changes, and 50.7% with no changes in sleep quality	Risk factors for negative changes in sleep: depression (OR = 1.19), anxiety (OR = 1.25), and stress (OR = 1.30).	4
Cancello et al[108]	Apr 15 to May 4, 2020	Italy	A cross-sectional study	n = 490	NA	80/410	NA	A self-reporting questionnaire	NA	43% reported worsen sleep quality, 4% with a new-onset persistent insomnia, 43% unchanged, and 13% improved.	NA	4
Goularte et al[109]	May 20 to July 14, 2020	Brazil	A cross-sectional study	n = 1996	34.22	320/1676	NA	DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure	NA	55.3%	NA	4

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Table 5 (Continued).

Author	Study Period	Country	Design	Participants	Age (Mean, yrs)	Male/ Female (n)	Response Rate (%)	Screening Tools	Cut-off Values	Prevalence	Factors Linked to Sleep Disturbance	Quality Assessment Score
Roitblat et al[110]	May 2020	11 countries	A prospective study	n = 14,000	NA	NA	NA	A sleep-wake patterns questionnaire; the simplified daily log, the expanded daily log, and phone/ Skype/Zoom interviews	NA	Decreased from 1.8% during the first 14-day period, to 0.5% after two months of stay-at-home	NA	4
Ustun[111]	Mar 23 to Apr 3, 2020	Turkey	A cross-sectional study	n = 1115	27.98	316/799	NA	A Personal Information Form	NA	19.4% with sleep problems	NA	4
Chakraborty et al[112]	Mar 29 to 31, 2020	India	A cross-sectional study	n = 507	33.9	382/125	NA	A 38-item self-designed questionnaire	NA	33.1% with disturbed sleep-wake cycle	NA	4
Hetkamp et al[113]	Mar 10 to Apr 30, 2020	Germany	A cross-sectional study	n = 16,245	NA	4695/11,500; other: 50	NA	Item of PHQ-9	≥3	13.5% reported severe reduced sleep quality	NA	4
Roy et al[114]	Mar 22 to 24, 2020	India	A cross-sectional study	n = 662	29.09	323/339	NA	A self-reported questionnaire	NA	12% of had sleeping difficulty	NA	4

Abbreviations: PSQI, Pittsburgh Sleep Quality Index; ISI, Insomnia Severity Index; AIS, Athens Insomnia Scale; ESS, Epworth Sleepiness Scale; JGLS, De Jong Gierveld Loneliness Scale; PHQ-2, Brief Patient Health Questionnaire 2; IUS, Intolerance to Uncertainty scale.

may have during COVID-19 lockdown. On the contrary, data from The Coconel Group showed an increase in the prevalence of sleep disturbance in young people aged 18–34 yrs when compared with older ones.[18] Consistently, three cross-sectional studies reported an increase of sleep problems in college students from baseline to lockdown.[123–125] It could be explained by the increased sleep vulnerability to stress caused by dramatic changes in their daily life and studies due to home confinement, school suspension, and reduced outdoor activity during the COVID-19 lockdown. Therefore, it could be speculated that the effects of age on sleep during COVID-19 pandemic are complicated and inconclusive, and could be interfered by other social-psychological factors.

Sex difference has been reported in the prevalence of sleep problems. Females seemed to be more prone to have sleep problems than males when facing COVID-19 crisis.[79,83,91,92,98,100,105,106] However, a longitudinal study showed that although females generally scored higher in PSQI and ISI scores within the 4-week home confinement period, they reported a reduction in insomnia and other accompanied psychological symptoms, while males had an increase in PSQI and ISI scores, indicating a narrowed sex gap in sleep quality after a prolonged lockdown.[99]

Perceived COVID-19-related stress is another major contributor for sleep disturbance, possibly through a change in emotional state (eg, stress, depression and anxiety).[82,86,89,91,101,107] Firstly, people who had direct or potential exposure to COVID-19[84,86,93] may be afraid of being infected and worry about being isolated and quarantined, all of which may exacerbate psychological distress and the accompanied symptoms of sleep disturbance. Secondly, post-traumatic stress due to the high mortality of COVID-19 and the unexpected death of someone close,[83] along with the loneliness due to social distancing or quarantine[90,98] increased psychological burden, making people prone to PTSD and sleep disturbance. Thirdly, negative attitude towards COVID-19, such as worries about COVID-19, perceived high death risk, perceived difficulty in treatment of COVID-19, being negative about COVID-19 control and emotion-focused coping style, may provoke cognitive arousal and disturb poor sleep quality.[79,81,87,97,101,104,106] Fourthly, the more negative impacts do COVID-19 have on livelihood, the more likely do people develop sleep disturbance.[81,83,89,98,104–106]

Additionally, geographical factors (eg, living in epicenters or in urban areas),[83,88,90,102] education experience,[89,97,98,100] marital status,[90] a history of chronic diseases or mental illnesses,[57,79,90,92,97,98,102] and changes in daily life[84,91,100,101,105,106] were also associated with sleep disturbance during COVID-19 pandemic.

Taken together, sleep disturbance in the general public, which is greatly influenced by social-psychological factors, could be compromised by reduced social jetlag and social sleep restriction during the pandemic. However, sleep disturbance-associated health consequences in the general public still need further investigation.

Limitation

There were several limitations in the review. Firstly, the majority of the included studies were cross-sectional design. More longitudinal studies are encouraged to determine the temporal changes of sleep disturbance during and after the pandemic. Secondly, the adoption of online surveys in most of the included studies limits the diagnosis of patterns of sleep disturbance and accurate assessment of disease severity. Thirdly, most of the included studies were descriptive. There is a lack of research to address the efficacy of targeted interventions including relaxation techniques, behavioral interventions, sleep medications by population on sleep disturbance and its associated health consequences. Fourthly, inclusion of studies in English only in the review may cause language bias.

Conclusion

In summary, COVID-19 exerts adverse impacts on sleep and brings great burden among various groups of populations. Sleep disturbance, mental illnesses, and physiologic illnesses form a vicious cycle to worsen the prognosis in COVID-19 patients. High workforce, shift work and COVID-19-related stress could increase the risk of sleep disturbance of HWs. For the general public, sleep quality seems more sensitive to social-psychological factors. Therefore, specific health strategies by population should be implemented to tackle sleep disturbance.

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