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CLINICAL REVIEW

Sleep disturbances during the COVID-19 pandemic: A systematic review, meta-analysis, and meta-regression

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S U M M A R Y

This systematic review and meta-analysis evaluated the extent of sleep disturbances during the COVID-19 pandemic. Eleven databases and six preprint repositories were searched for the period from November 1, 2019, to July 15, 2021. The DerSimonian and Laird method was used to develop random-effect meta-analyses. Two hundred and fifty studies comprising 493,475 participants from 49 countries were included. During COVID-19, the estimated global prevalence of sleep disturbances was 40.49% [37.56; 43.48%]. Bayesian meta-analysis revealed an odds of 0.68 [0.59; 0.77] which translates to a rate of approximately 41%. This provides reassurance that the estimated rate using classical meta-analysis is robust. Six major populations were identified; the estimated prevalence of sleep problem was 52.39% [41.69; 62.88%] among patients infected with COVID-19, 45.96% [36.90; 55.30%] among children and adolescents, 42.47% [37.95; 47.12%] among healthcare workers, 41.50% [32.98; 50.56%] among special populations with healthcare needs, 41.16% [28.76; 54.79%] among university students, and 36.73% [32.32; 41.38%] among the general population. Sleep disturbances were higher during lockdown compared to no lockdown, 42.49% versus 37.97%. Four in every ten individuals reported a sleep problem during the COVID-19 pandemic. Patients infected with the disease, children, and adolescents appeared to be the most affected groups.

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Abbreviations: AIS, Athens insomnia scale; Decimal, data extraction for complicated meta-analysis; DOI, digital object identification; GOSH, Graphic display of study heterogeneity; IPD, individual patient data; ISI, Insomnia severity index; MeSH, Medical Subjects Headings; NOS, Newcastle–Ottawa Scale; Prisma, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PSQI, Pittsburgh sleep quality index.

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Introduction

Because sufficient sleep is necessary for humans to sustain everyday functioning [1], numerous research studies of sleep disturbances were conducted during the COVID-19 pandemic, most using self-report data [2]. These studies have reported a range of results on the prevalence and associated factors of sleep disturbances during COVID-19 in various populations.

Several systematic reviews and meta-analyses examining the impact of COVID-19 on sleep disturbances have been conducted. The first review reported a systematic review and meta-analysis of the pooled prevalence rate of sleep disturbances during the COVID-19 pandemic [2]. The review concluded that the global prevalence of sleep disturbances was approximately 36%; the least affected group was the general population with a rate of 32%, followed by healthcare workers with a rate of 36%, and patients with COVID-19 were the most affected with a rate of 75% [2]. A more recent systematic review and meta-analysis estimated a similar prevalence of sleep disturbances among the general population, 31% [3] to the 32% initially reported by Jahrami and colleagues (2). Similar findings of healthcare workers were confirmed by two independent meta-analyses that reported a pool rate of 35% [4] and 38% [5]. Nurses appeared to have a slightly higher rate of sleep disturbances with a reported rate of 43% [6]. According to the same review, the adjusted pooled estimated prevalence of sleep disturbances was 24% for females and 27%, for males [3]. A review focused on children and adolescents reported a combined prevalence of any sleep disruption in children was 54% [7]. Furthermore, a high rate of sleep disturbances was reported among Chinese healthcare workers, with a reported rate of 45% [8]. Reviews of sleep disturbances in patients infected with COVID-19 produced heterogenous findings as follows 34% [9], 57% [10], and 75% [2].

In all previous systematic reviews and meta-analyses, heterogeneity or variation in study outcomes between studies was high despite efforts to control moderators using subgroup analysis or a meta-regression analysis. While results of moderator analyses resulted in better fit indices of heterogeneity; nonetheless, it remained high. Previous reviews typically controlled for one moderator at the time, and no review has attempted a multiple meta-regression analysis to correct for interaction between variables at the metadata level. Risk of bias assessment was examined coarsely as part of some of the previous systematic reviews and meta-analyses with findings presented as aggregate scores and not utilized to influence the synthesis of the studies' conclusions or to factor into the overall reliability evaluation of the evidence.

Ten previous systematic reviews and meta-analyses were performed and published before our review [2–11]; and were critically appraised as a preparatory step. While there is some value in independent replications of meta-analyses by different teams, the specific purpose of this review was not to perform an updated systematic review and meta-analysis but to fill identified gaps in previous multiple overlapping meta-analyses covering the topic of sleep disturbances during COVID-19. Several important information gaps were identified in evaluating the previously published reviews. First, seven out of ten were narrowly focused on a single population, mainly healthcare workers [4–6,8,11], children and adolescents [7], or patients with COVID-19 [9]. Therefore, several significant populations were missed, for example, university students or those with medical comorbidities. Second, previous studies that focused on healthcare workers did not control for the line of work, i.e., frontline healthcare workers vs. non-frontline healthcare workers. Thus, it remained unknown if the proportion of frontline healthcare workers in the analyzed study or nursing staff (as the primary direct care providers) during the pandemic will affect the reported estimated rate. Third, previous work examined the role of lockdown during the COVID-19 pandemic and reported an association between lockdown status, per se, and prevalence of sleep disturbances [10] but did not explicitly quantify or report the magnitudes of sleep disturbances during lockdown compared to no lockdown. Accordingly, neither lockdown status nor the year of publication as a proxy for the longitudinal effect were analyzed or reported in previously published studies. Finally, all previously published reviews relied exclusively on classical meta-analytic techniques. Consequently, statistical approaches (e.g., Bayesian analysis) guided by combining prior information about what is already known with data in a new sample were not previously utilized to ensure the stability of results.

Given the now large number of published studies on the topic, the current systematic review was designed and conducted to estimate the raw and weighted prevalence rates of sleep disturbances during the pandemic taking into account the effect of a single moderator and simultaneous interaction of several moderators on the prevalence of sleep disorders in diverse populations. The findings provide a more precise prevalence estimate of sleep disturbances during COVID-19 across multiple at-risk populations and may aid in the development of customized screening and intervention techniques to reduce the harmful consequences of these sleep disturbances.

Methodology

Registration and protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Prisma) criteria were used to design and perform this systematic review and meta-analysis [12]. The protocol was registered into the PROSPERO International Prospective Register of Systematic Reviews (Prospero) database (Registration number: CRD42021268440). Before registering our protocol, a careful review of the Prospero and the COVID-19 evidence network to support decision-making (COVID-END) resources was performed to verify if a similar systematic review already existed to avoid duplication.

Search strategy

Eleven electronic academic databases (American Psychological Association PsycINFO; Cochrane Library; Cumulative Index to Nursing and Allied Health Literature (CINAHL); EBSCOhost Research Platform; Embase; Google Scholar; MEDLINE; ProQuest Medical; ScienceDirect; Scopus; and Web of Science were searched systematically between November 1, 2019 and July 15, 2021. Additionally, the COVID-19 Global literature on coronavirus disease database by World Health Organization was also searched to cover six preprint repositories (arXiv.org; biorxiv.org; medRxiv.org; Preprints.org; psyarxiv.com; and SSRN.com) for publications that have been peer-reviewed and accepted but not yet indexed. There was no limit on the language used.

The search strategy involved crossmatching keywords selected based on key terms and the PubMed Medical Subjects Headings (MeSH). The Boolean logic operators of (OR, AND, NOT) were used to develop the search in an [All Fields] search. Each database's advanced search characteristics were used to change the search syntax. In the search, the following keywords were used: "COVID-19″ OR "2019-nCoV" OR "2019 coronavirus" OR "Wuhan coronavirus" OR "2019 novel coronavirus" OR "SARS-CoV-2" AND "sleep" OR "sleep medicine" OR "sleep disturbances" OR "sleep disorders" OR "sleep problems" OR "polysomnography" OR "sleep quality" OR "PSQI" OR "Pittsburg Sleep Quality Index" OR "insomnia" OR "circadian rhythm" OR "restless leg syndrome" OR "sleep apnea" OR "narcolepsy" OR "daytime dysfunction" OR "daytime sleepiness"

OR “ESS” or “Epworth Sleepiness Scale” AND “prevalence” OR “incidence” OR “epidemiology” OR “rate” OR “frequency” OR “risk factors” OR “interventions” OR “treatment” OR “therapy” OR “management”.

To enhance the chance of obtaining relevant original studies, the reference lists of included studies and previous systematic reviews and meta-analyses of published articles were manually searched.

Finally, the final search results were converted into a Microsoft Excels spreadsheet 2019 to filter and eliminate duplicates. Research Information Systems, incorporated files were saved to manage the citations using EndNote X9.3.3.

Inclusion and exclusion criteria

The magnitude of sleep disturbances during the COVID-19 pandemic was the primary outcome of the current meta-analysis. As a result, we included: First, all observational studies that looked at the impact of COVID-19 on sleep quantity and quality in a variety of groups, including the general population, healthcare workers, COVID-19-infected patients, children and adolescents, university students, and people with special healthcare needs (e.g., pregnant women or people with chronic medical conditions). Second, studies that reported numerical values of the prevalence of sleep disturbances expressed in event counts and total sample size. We used an artificial intelligence application - WebPlotDigitizer [13] - to obtain the underlying numerical data, reverse plots of data visualizations if they were not reported in the text of the original studies. Third, only English language, peer-reviewed studies published between November 1, 2019, and July 15, 2021, were included.

There were no restrictions on the characteristics of the participants. Abstracts, case reports, editorials, infographics, letters, narrative reviews, opinions, position statements, and systematic reviews and meta-analyses were excluded from the retrieved articles. Fig. 1 shows the Prisma flow diagram for study selection.

Outcomes

The primary outcome was the estimated prevalence of sleep disturbances during the COVID-19 pandemic. Sleep disturbances refer to a group of disturbances characterized by trouble falling or staying asleep, which can result in excessive drowsiness throughout the day as a result of sleep deprivation or change in terms of quantity, quality, or timing [10]. Sleep disturbances as an outcome had to be measured with valid and reliable psychometric instruments or validated with established cut-off points before being labeled as such. For example, on the Pittsburgh sleep quality index [14], a global score of five or above indicates poor sleep quality indicative of a “sleep problem”.

Study screening and selection

In the first phase, two reviewers independently evaluated the title and abstract of all retrieved publications based on the inclusion criteria (HJ, AH, AFA, FFR). Based on the aforementioned criteria, the

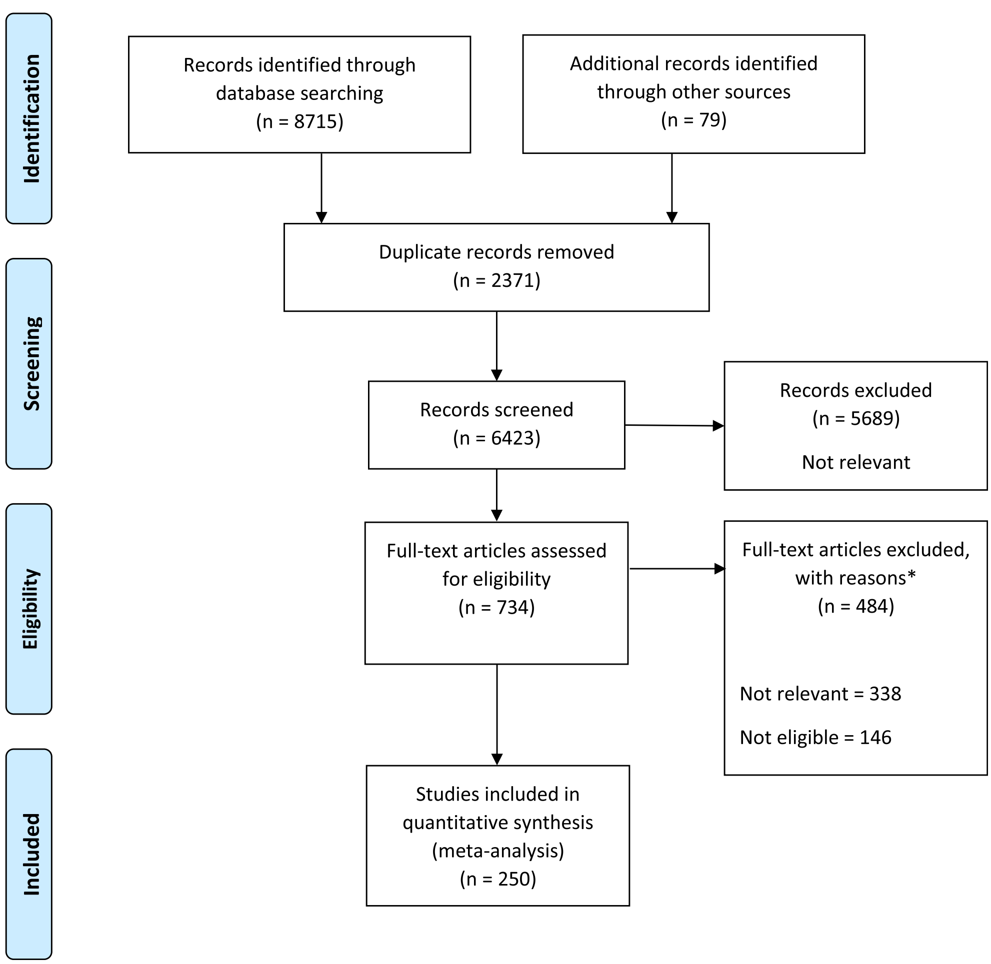

Fig. 1. PRISMA flow diagram of study inclusion.

complete texts of possibly relevant papers were studied further. Relevant studies were chosen during this procedure. Disagreements between reviewers were addressed by a third member of the study team (AB) through discussion and consensus.

Data extraction

The recommendations for data extraction for complicated meta-analysis (Decimal) [15] were used to design data extraction for this review. To extract data from the studies that were included, a predesigned electronic form was created in a Microsoft Excel Spreadsheet. To facilitate the work of geographically dispersed researchers, the form was available live online within a secure, shared workspace for the extraction team members.

Study information, epidemiological findings, and the article's reference were all part of the data extraction process. The research information included the last author, year of publication, country of origin, kind of study, study goals, sample size, recruitment strategy, and basic sample characteristics such as mean age and proportion of females. The prevalence rate for sleep quality (count of events and sample size) and other noteworthy findings were the epidemiological findings. The complete citation information of the publication, including the digital object identification (DOI), was provided in the citation. We contacted the corresponding authors for clarifications and to seek more information when necessary. Each entry was extracted by two reviewers independently (OH, AH, AFA, FFR) and was matched by (ZS); discrepancies/disagreements between reviewers were settled through discussion and consensus with a third author (HJ).

Quality assessment and risk of bias

The Newcastle–Ottawa Scale (NOS) was used to evaluate the methodological quality and assess the risk of bias of the studies included in the current review. The NOS checklist was used to look at three aspects (participants selection, comparability, and outcome and statistics). There are three variants of the checklist: for cross-sectional studies (seven items), for case–control studies (eight items), and for cohort or longitudinal studies (eight items). NOS is based on a star rating system, with each study receiving a maximum of nine stars (cross-sectional and cohort studies) or ten stars (case–control studies). A study with a score $\geq$8 has good quality and low risk of bias, a score of 5–7 has moderate quality and moderate risk of bias), and a score of 0–4 has low quality and high risk of bias [16]. Based on this quality ranking, no studies were eliminated. On the other hand, subgroup analysis was used to examine the impact of quality on the pooled effect size. Quality evaluation was done in parallel with data extraction by the same researchers, and the quality score for each study was determined using a consensus method.

Quality assessment results are presented visually using the traffic light plot, which tabulates the judgment for each study in each area of the NOS. A summary plot (weighted) was also created to depict the proportion of information within each judgment for each domain for all studies.

Data analysis

Because the studies included were of diverse populations, a random effect model was used to account for both within-study and between-study variations. Our meta-analysis utilized the general inverse variance approach [17], the logit transformed proportions, and corresponding standard errors with the DerSimonian and Laird estimates of effect size [18]. Clopper-Pearson interval was used for the 95% confidence interval calculation [19]. The I^2 statistic was used to quantify the variability of sample size impact estimates across these investigations [20]. The I^2 statistic indicates how much variance between research is attributable to heterogeneity rather than chance [21]. Heterogeneity is classified as 1) mild when the I^2 is less than 25%, 2) moderate when the I^2 is 25–50%, 3) severe when the I^2 is 50–75%, and 4) extremely severe when the I^2 is higher than 75% [21].

Cochran's Q test [22] and τ^2 [23] statistics were used to determine the degree of heterogeneity between the studies. The weighted sum of squared differences between individual study effects and the pooled effect across studies was computed as Cochran's Q, with the weights being those used in the pooling technique [22]. The chi-square statistic with k (number of studies) minus 1 degree of freedom was used to distribute Q [22]. The τ^2 statistic is the variation of effect size parameters across all studies in a population, and it represents the variance of real effect sizes; τ refers to the square root of this integer. To further examine heterogeneity, the H statistic was defined as the ratio of the standard deviation of a random-effects meta-analysis' estimated overall effect size to the standard deviation of a fixed-effects meta-analysis [20].

In our meta-analysis, the Baujat plot was employed to investigate heterogeneity [24]. Each study's contribution to the total heterogeneity statistic is displayed on the x-axis. The standardized difference of the total prevalence of sleep disturbances with and without each study is displayed on the y-axis; this amount represents the impact of each study on the overall treatment effect.

The findings of meta-analyses are plotted as a point estimate with 95% confidence intervals in a forest plot [25]. A jackknife approach was used to establish that no single study drove our findings by doing a leave-one-out sensitivity analysis [26]. The inclusion of outliers and influential studies may compromise the validity and robustness of the meta-analysis results. Thus, outliers were identified and removed. An outlier is labeled if the study's confidence interval does not coincide with the pooled effect's confidence interval [27]. Funnel plots were used as a visual approach to examine publication bias [28]. A funnel plot is a basic scatter plot of individual study intervention effect estimates versus some metric of study size or precision. The impact estimates are plotted on the horizontal scale, with the study size measured on the vertical axis, as with forest plots. This is the polar opposite of traditional scatter plot graphical presentations, which exhibit the result (e.g., effect size) on the vertical axis and the covariate (e.g., study size) on the horizontal axis [28]. Kendall's τ rank-order correlations [29] and Egger's regression [30] were used to analyze publication bias in a formal way. The use of Duval and Tweedie's trim and fill technique [31] to produce modified point estimates to account for funnel plot asymmetry due to possible publication bias was planned a priori. Because the most extreme findings on one side of the funnel plot are suppressed, the technique may be used to estimate the number of studies missing from a meta-analysis [31]. The technique then adds data to the funnel plot to make it more symmetric. The approach should not be thought of as a way to get a more valid assessment of the overall effect or outcome, but rather as a tool to see how sensitive the results are to one specific selection process [31]. The adjusted prevalence rate was reported if both Kendall's τ rank order correlation and Egger's regression were significant.

The p-curve approach, which focuses on p-values as the major driver of publication bias, was used to determine whether there is a real impact behind our meta-analysis data and to estimate its size [32,33]. Importantly, unlike small-study impact approaches, it accounts for dubious research procedures such as p-hacking. Graphic display of study heterogeneity (GOSH) plots was also utilized as a diagnostic plot to examine effect size heterogeneity [34]. Within the modeled data, GOSH charts make it easier to find outliers as well as clear homogenous groupings [34].

To explain the dispersion of effect sizes or heterogeneity, a moderator analysis was done. Because estimates of the prevalence of sleep disturbances differ depending on the types of populations studied, subgroup meta-analyses were performed to see if sleep disorders in each of the groups had an impact on the overall pooled estimate. Subgroup analysis was used to look at variations between groups based on categorical factors, such as the study population and the research measure. When three or more studies were available for analysis, subgroup analysis was conducted, and results were presented. We reported subgroup analysis based on country, population, used sleep measure, lockdown status, year of publication (time effect), research design, and quality assessment. The different aspects of sleep disturbances described, such as insomnia or sleep quality, were analyzed and presented separately according to the sleep measurement tool utilized in the included studies. The primary two disturbances reported were poor sleep quality measured using the Pittsburgh sleep quality index (PSQI); and insomnia measured using the insomnia severity index (ISI), the Athens insomnia scale (AIS).

For countries, we reported results if $\geq$ 10 studies were available for a given country. Special populations were defined as pregnant women, the elderly, and individuals with chronic diseases. Healthcare workers include physicians, nurses, emergency medical personnel, dental professionals, diagnostics professionals, pharmacists, and administrative staff. Those personnel in organizations committed to the assessment, quarantine, isolation, and treatment of established COVID-19 cases are designated as frontline healthcare workers in our analysis.

We utilized meta-regression approaches to look for continuous variables of sleep difficulties; we used four covariates, mean age, female sex proportion, front-line staff proportion (for studies involving healthcare workers) and proportion of nurses (for studies involving healthcare workers), and the interaction term of the proportion of nurses working on the front-line (for studies involving healthcare workers).

To further strengthen the results of the classical meta-analysis, Bayesian meta-analysis was also conducted. Meta-analysis using Bayesian methods has some advantages over many classical methods [35]. First, the analysis naturally considers the imprecision of the estimated between-study variance estimates [35]. Second, the analysis includes the impact of data on people's beliefs [20]. Finally, the analysis includes external evidence, such as information about the effects of interventions or likely differences between studies. Bayesian meta-analysis uses the Bayesian hierarchical model [36]. As with the conventional random-effects model, this model relies on the same basic assumptions [36]. There is a difference, however, in that prior distribution (informative, weakly informative, or uninformative) is assumed for μ and τ^2. The prior distribution describes the uncertainty surrounding a particular effect measure within a meta-analysis, such as the odds ratio or the mean difference [36]. There may be subjective beliefs about the size of the effect, or it may be based on sources of evidence excluded from the meta-analysis, such as non-randomized studies. Quantity uncertainty is reflected by the width of the prior distribution [37]. It is possible to use a ‘non-informative prior when there is little or no available information, in which all values are equally likely [37]. Meta-analysis likelihood summarizes both the data from included studies and the model of the meta-analysis (assuming random effects) [35,37].

All data analyses and visualizations were performed using R for statistical computing version 4.1.0 [38]. The packages ‘meta’ [39] and ‘metafor’ [40] were used to perform all meta-analytics. The package ‘bayesmeta’ [41] was used to perform Bayesian meta-analysis. Quality assessment plots were produced using risk-of-bias visualization ‘robvis’ [42].

Role of the funding source

No governmental, commercial, or non-profit sector has provided support for this systematic review and meta-analysis.

Results

Features of the studies included

The search was performed for the period between November 1, 2019, and July 15, 2021. Through electronic database searches and other sources, a total of 8715 records were identified. There were 6771 records left after duplicates were removed. A total of 734 prospective articles were evaluated in their entirety. Narrative and systematic reviews, editorials, comments, letters to the editor, position statements, irrelevant literature, duplicates, and incorrectly categorized publications were among the 485 papers eliminated. The search procedure is depicted in Fig. 1 using the PRISMA flowchart.

A total of 250 studies [285 subgroups, i.e., multiple populations, multiple tools, or multiple data points] comprising 493,475 participants from 49 countries were included in the analyses [43–292]. The countries included Argentina (K = 3), Australia (K = 3), Austria (K = 1), Bahrain (K = 1), Bangladesh (K = 4), Belgium (K = 1), Brazil (K = 7), Canada (K = 5), China (K = 84), Colombia (K = 2), Cyprus (K = 1), Egypt (K = 6), Ethiopia (K = 2), Finland (K = 1), France (K = 4), Germany (K = 2), Greece (K = 5), India (K = 16), Indonesia (K = 2), Iran (K = 3), Iraq (K = 2), Israel (K = 2), Italy (K = 34), Jordan (K = 2), Kuwait (K = 1), Libya (K = 1), Mali (K = 1), Morocco (K = 2), Multicountry (K = 17), México (K = 1), Nepal (K = 2), Netherlands (K = 1), Nigeria (K = 1), Oman (K = 3), Pakistan (K = 1), Poland (K = 2), Qatar (K = 2), Russia (K = 1), Saudi Arabia (K = 10), Slovenia (K = 1), Spain (K = 10), Sweden (K = 1), Taiwan (K = 1), Thailand (K = 1), Tunis (K = 2), Turkey (K = 12), UK (K = 2), USA (K = 15), and Vietnam (K = 1). A total of 249 (99.60%) of the studies collected data online; only one study used a telephone survey and aimed to include the elderly [123]. In 139 (55.60%) studies the data were obtained during the specific countries' national lockdown periods. In terms of included studies, the top three countries were China, Italy, India with (84, 33.60%), (34, 13.60%), and (16, 6.40%), respectively.

The mean sample size was 1804 [95%CI 1237; 2376 participants]. Participants were mainly females 64% [95%CI 62%; 66%], and the mean age of participants was 35 years [95%CI 33; 37 years]. A total of six participants grouping clusters were identified: general population 98 (39%), healthcare workers 84 (34%), special population 22 (9%), university students 18 (7%), COVID-19 patients 15 (6%), and children and adolescents 13 (5%). Participants from the healthcare workers included: 37% [95%CI 28%; 45%] from the frontline workforce, and 40% [95%CI 32%; 47%] were from nursing staff only. Cross-sectional design 229 (91%) was the most common, followed by longitudinal 12 (5%) or case–control 9 (4%) designs. Sleep disturbances were assessed using a variety of measures; the most common were: the PSQI, 95 (38%) of the studies, the ISI 94 (37.60%) of the studies, the AIS 12 (4.80%) of the studies, and other sleep measures 49 (19.60%) of the remaining studies. A prevalence rate was calculated as the number of people with sleep disturbances divided by all the individuals in a sample. All studies were published after March 2020, and 93 (37%) were released in 2021. Studies published in 2020 and 2021 did not differ significantly in terms of populations, P = 0.32, or used research design, P = 0.90. However, studies published in 2021 compared to those published in 2020 were mostly during lockdown periods P = 0.001 and relied mainly on the PSQI as a research measure P = 0.001. Furthermore, more studies in 2021 came from the countries that did not publish in 2020, P = 0.002. The mean NOS quality score was 7.10 ± 1.12 and ranged from 4.0 to 8.0. Detailed examination of quality assessment for each study included in the meta-analysis is presented in Fig. S1. Summary results indicate that 95% of the studies were of high or moderate quality. According to Fig. 2, most of the risk bias is observed in the selection dimension, specifically regarding the sample size and representativeness of the sample. The summary features of all included studies are listed in Table 1.

Sleep disturbances: a meta-analysis

Global assessment of sleep disturbances

Using all available studies, a random-effects meta-analysis evaluated the prevalence of sleep disturbances in all populations (K = 285, N = 493,475) generated a pooled prevalence rate of 40.49% [37.56; 43.48%], heterogeneity (Q = 87,213 (284), P = 0.001), τ^2 = 1.09 [0.86; 1.30], τ = 1.04 [0.93; 1.14], I^2 = 99.7%; H = 17.52 [17.28; 17.78]. Using any sleep measure in all populations, the raw prevalence estimates for sleep disturbances varied from 2% to 95%. The forest plot of the meta-analysis of sleep disturbances in all populations using all measures is shown in Fig. S2.

A (leave-one-out) sensitivity analysis found that no study had a greater than 1% impact on the global prevalence estimate, Fig. S3. Influence analysis was used to identify and eliminate outliers in our meta-analyses. Results of influence meta-analysis yielded a pooled prevalence rate of 40.70% [39.81; 41.59%], heterogeneity (Q = 270 (76), P = 0.001), τ^2 = 0.02 [0.01; 0.04], τ = 0.12 [0.10; 0.19], I^2 = 72.20% [65.10%; 77.90%], H = 1.90 [1.69; 2.13]. The influence on pooled result and overall heterogeneity contribution from the analysis is shown in a Baujat plot in Figure S4.

After using the leave-one-out method and influence analyses to test the robustness of our meta-analysis, the GOSH plot in Fig. S5 revealed several distinct clusters, indicating that there may be more than one effect size population in our data, necessitating a subgroup analysis and the preservation of outliers. GOSH diagnostics indicated that the number of K-means clusters detected ≥3 is shown in Fig. S6.

Visual inspection to funnel plot indicated a slight publication bias (Fig. 3), Egger's regression P = 0.001 confirmed the publication bias; however, this was not evident in the radial plot (Fig. 4) and rank correlation by Kendall's τ without continuity correction, P = 0.06. The trim-and-fill technique was used to estimate and compensate for the quantity and findings of missing studies, and results showed that adjusted prevalence of sleep disturbances with K = 353 (68 added studies) is 30.50% [27.93; 33.19%], heterogeneity (Q = 124,771 (352), P = 0.001), τ^2 = 1.39 [1.27; 1.84], τ = 1.18 [1.12; 1.35], I^2 = 99.70%; H = 18.83 [18.60; 19.06].

Meta-regression analysis revealed that neither age nor sex moderates the global prevalence rate of sleep disturbances during the COVID-19 pandemic P = 0.15 and P = 0.92, respectively. Detailed results are presented in Table 2.

Bayesian meta-analysis of the global assessment of sleep disturbances revealed that the mean odds of quotes estimate was 0.68 [0.59; 0.77], τ = 1.09 [1.00; 1.18]. Thus, converting the odds obtained by Bayesian meta-analysis translates to an overall proportion of approximately 41%; detailed results are shown in Figure S7.

Assessment of sleep disturbances during COVID-19 by country

Seven countries had 10 or more studies and showed a statistically significant difference between the groups Q = 4808 (48), P = 0.001. Prevalence rate of sleep disturbances were as follow: China 30.32% [26.26; 34.72%], τ^2 = 0.87, It = 99.70%; Italy 38.64% [28.86; 49.44%], τ^2 = 1.67, I^2 = 99.80%; India 27.25% [19.00; 37.43%], τ^2 = 0.89, It2 = 98.20%; USA 50.21% [41.06; 59.35%], τ^2 = 0.52, I^2 = 98.80%; Turkey 44.18% [33.41; 55.53%], τ^2 = 0.62, I^2 = 98.0%; Spain 58.59% [47.64; 68.76%], τ^2 = 0.45, I^2 = 92.80%; and Saudi Arabia 51.10% [36.67; 65.35%], τ^2 = 0.89, I^2 = 99.20%.

Age (older age) was a statistically significant moderator in China and Spain, P = 0.02 and P = 0.04, respectively. Detailed results are presented in Table 2 and Figure S8.

Assessment of sleep disturbances during COVID-19 by population

Subgroup analysis by population revealed that: patients infected with COVID-19 are the most affected population group by sleep disturbances with an overall pooled rate of 52.39% [41.69; 62.88%], K = 16, N = 6821, I^2 = 98.10%, H = 7.31, τ^2 = 0.70, and τ = 0.84. Children and adolescents appeared the second most affected population group by sleep disturbances with an overall pooled rate of 45.96% [36.90; 55.30%], K = 13, N = 29,006, I^2 = 99.30%, H = 12.29, τ^2 = 0.45, and τ = 0.67. Healthcare workers, special populations, and university students had a similar pooled prevalence rate of sleep disturbances during COVID-19. Specifically, data for healthcare workers K = 90, N = 63,685 showed an overall rate of sleep disturbances during COVID-19 pandemic of 42.47% [37.95; 47.12%], I^2, 99.1%, H = 0.47, τ^2 = 0.82, and τ = 0.90. Special populations K = 23, N = 8023, showed an overall rate of sleep disturbances during COVID-19 pandemic of 41.50% [32.98; 50.56%], I^2 = 98.1%, H = 7.19, τ^2 = 0.77, and τ = 0.88. University students K = 22, N = 21,880, showed an overall rate of sleep disturbances during COVID-19 pandemic of 41.16% [28.76; 54.79%], I^2 = 99.6%, H = 16.08, τ^2 = 1.69, and τ = 1.30. Finally, the general population K = 121, N = 364,060 had the lowest rate of sleep disturbances during COVID-19 pandemic with an overall rate of 36.73% [32.32; 41.38%], I^2 = 99.8%, H = 23.17, τ^2 = 1.18, and τ = 1.09. Forest plots of the results are shown in Fig. S9. Assessment of publication bias using funnel plots revealed no significant publication bias within each group, results was confirmed by Kendall's and Egger's tests. Detailed results are presented in Table 2.

Moderator analysis revealed that age (older age) was associated with a higher risk of sleep disturbances in healthcare workers P = 0.03; and sex (larger proportion of female) was associated with

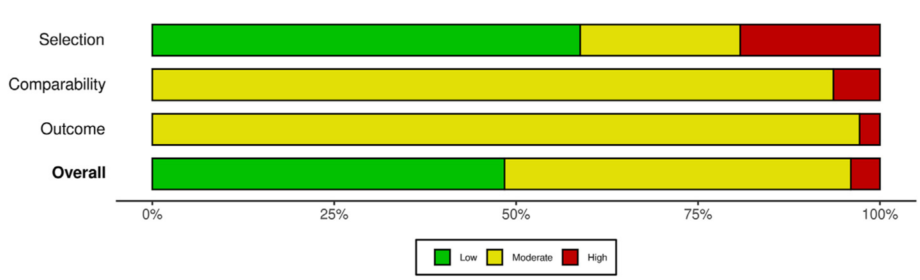

Fig. 2. The summary risk of bias plot of included studies.

Table 1
Key features, methodologies, and measures of studies that were included in this review about sleep disturbances during COVID-19.

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
1	Abbas et al., 2021 [43]	Kuwait	Yes	Healthcare workers [Frontline = 64.98%, Nurses = 0%]	Cross-sectional design, N = 217, Female = 43.8%, Age = 35.8 years.	PSQI	5
2	Abdellah et al., 2021 [44]	Multi	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 344, Female = 71.5%, Age = 35.6 years.	PSQI	7
3	Abdulah et al., 2020 [45]	Iraq	No	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 268, Female = 29.9%, Age = 35.1 years.	AIS	8
4	Agberotimi et al., 2020 [46]	Nigeria	Yes	General Population	Cross-sectional design, N = 884, Female = 45.5%, Age = 28.8 years.	ISI	8
5	Ahmad et al., 2020 [47]	India	Yes	General Population	Cross-sectional design, N = 393, Female = 47.2%, Age = 30.3 years.	SD	6
6	Akıncı et al., 2021 [48]	Turkey	No	COVID-19 patients	Cross-sectional design, N = 189, Female = 41%, Age = 46.3 years.	PSQI	7
7	Al Ammari et al., 2021 [49]	Saudi Arabia	No	Healthcare workers [Frontline = 27.78%, Nurses = 36.39%]	Cross-sectional design, N = 720, Female = 64.2%, Age = 18–40 years.	ISI	8
8	Al Maqbali et al., 2021 [50]	Oman	Yes	Healthcare workers [Frontline = 81.4%, Nurses = 100%]	Cross-sectional design, N = 1130, Female = 91.2%, Age = 36.9 years.	PSQI	7
9	Al-Ajlouni et al., 2020 [51]	Jordan	Yes	General Population	Cross-sectional design, N = 1240, Female = 47.1%, Age = 37.4 years.	PSQI	7
10	Alamrawy et al., 2021 [52]	Egypt	No	General Population	Cross-sectional design, N = 447, Female = 70.2%, Age = 20.7 years.	ISI	8
11	AlAteeq et al., 2021 [53]	Saudi Arabia	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 1313, Female = 44.2%, Age = 34.8 years.	ISI	7
12	Alessi et al., 2020 [54]	Brazil	No	Special Population	Cross-sectional design, N = 120, Female = 55.8%, Age = 54.8 years.	MSQ	6
13	Alfonsi et al., 2021 [55]	Italy	Yes	General Population	Longitudinal design, N = 217, Female = 72%, Age = 35.7 years.	PSQI	7
14	Alharbi et al., 2021 [56]	Saudi Arabia	Yes	General Population	Cross-sectional design, N = 790, Female = 53.1%, Age = 40–60 years.	PSQI, AIS	7
15	Ali et al., 2021 [57]	Bangladesh	No	Healthcare workers [Frontline = 4.1%, Nurses = 9.5%]	Cross-sectional design, N = 294, Female = 43.5%, Age = 28.9 years.	ISI	5
16	Almater et al., 2020 [58]	Saudi Arabia	No	Healthcare workers [Frontline = 64.5%, Nurses = 0%]	Cross-sectional design, N = 107, Female = 43.9%, Age = 32.9 years.	ISI	6
17	Alnofaiey et al., 2020 [59]	Saudi Arabia	No	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 462, Female = 49.1%, Age = 20–60 years.	PSQI	8
18	Alomayri et al., 2020 [60]	Saudi Arabia	No	Special Population	Cross-sectional design, N = 400, Female = 86%, Age = 18–55 years.	PSQI	8
19	Alqahtani et al., 2021 [61]	Saudi Arabia	Yes	General Population	Cross-sectional design, N = 593, Female = 42.3%, Age = 36.5 years.	PSQI	7
20	AlRasheed et al., 2021 [62]	Saudi Arabia	Yes	General Population	Cross-sectional design, N = 344, Female = 63%, Age = 27.5 years.	PSQI	7
21	Alshekaili et al., 2020 [63]	Oman	Yes	Healthcare workers [Frontline = 50.4%, Nurses = 39.5%]	Cross-sectional design, N = 1139, Female = 80%, Age = 36.3 years.	ISI	7
22	Ammar et al., 2020 [64]	Multi	No	General Population	Longitudinal design, N = 1047, Female = 53.8%, Age = 18–55 years.	PSQI	8
23	Amra et al., 2021 [65]	Iran	Yes	Healthcare workers [Frontline = 0%, Nurses = 65.1%]	Cross-sectional design, N = 372, Female = 65.8%, Age = 34.5 years.	PSQI, ISI	7
24	Assenza et al., 2020 [66]	Italy	No	General Population	Cross-sectional design, N = 928, Female = 74.5%, Age = 18–86 years.	PSQI	8
25	Atas et al., 2021 [67]	Turkey	Yes	Special Population	Cross-sectional design, N = 106, Female = 38.7%, Age = 44.2 years.	PSQI, ISI	5
26	Bacaro et al., 2020 [68]	Italy	Yes	General Population	Cross-sectional design, N = 1989, Female = 76.2%, Age = 38.4 years.	ISI	8
27	Badellino et al., 2020 [69]	Argentina	No	General Population	Cross-sectional design, N = 1985, Female = 75.9%, Age = 36.8 years.	PSQI	8
28	Bai et al., 2020 [70]	China	Yes	Healthcare workers [Frontline = 0%, Nurses = 74.6%]	Cross-sectional design, N = 118, Female = 63.6%, Age = 33.1 years.	PSQI	5
29	Bajaj et al., 2020 [71]	India	Yes	General Population	Cross-sectional design, N = 391, Female = 53.5%, Age = 19–41 years.	ISI	8
30	Barrea et al., 2020 [72]	Italy	Yes	General Population	Longitudinal design, N = 121, Female = 64.5%, Age = 44.9 years.	PSQI	6
31	Barua et al., 2021 [73]	Bangladesh	No	Healthcare workers [Frontline = 100%, Nurses = 0%]	Cross-sectional design, N = 370, Female = 39.7%, Age = 30.5 years.	SCI-02	8
32	Baskan et al., 2021 [74]	Turkey	Yes	General Population	Cross-sectional design, N = 1909, Female = 69%, Age = 31.9 years.	PSQI	7
33	Beck et al., 2020 [75]	France	Yes	General Population	Cross-sectional design, N = 1005, Female = 52%, Age = NR years.	SD	6
34	Benham et al., 2020 [76]	USA	Yes	University Students	Longitudinal, N = 1222, Female = 69%, Age = 21.3 years.	PSQI, ISI	7
35	Bezerra et al., 2020 [77]	Brazil	Yes	General Population	Cross-sectional design, N = 3836, Female = 73.5%, Age = 18-7 years.	SD	6

(continued on next page)

Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
36	Bhat et al., 2020 [78]	India	No	General Population	Cross-sectional design, N = 264, Female = 27.7%, Age = 18–60 years.	PSQI	8
37	Bigalke et al., 2020 [79]	USA	Yes	General Population	Cross-sectional design, N = 103, Female = 59%, Age = 38 years.	PSQI	6
38	Blekas et al., 2020 [80]	Greece	No	Healthcare workers [Frontline = 0%, Nurses = 50%]	Cross-sectional design, N = 270, Female = 73.7%, Age = 18–75 years.	AIS	8
39	Bohlken et al., 2020 [81]	Germany	Yes	General Population	Cross-sectional design, N = 396, Female = NR%, Age = 23.9 years.	SD	6
40	Brito-Marques et al., 2021 [82]	Brazil	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 332, Female = 68.4%, Age = 36 years.	PSQI	6
41	Caballero-Domínguez et al., 2020 [83]	Colombia	Yes	General Population	Cross-sectional design, N = 700, Female = 68%, Age = 37.1 years.	AIS	8
42	Cai et al., 2020 [84]	China	No	Healthcare workers [Frontline = 50%, Nurses = 50%]	Case-Control design, N = 2346, Female = 70%, Age = 30.6 years.	ISI	8
43	Cai et al., 2020 [85]	China	No	Healthcare workers [Frontline = 45.9%, Nurses = 100%]	Cross-sectional design, N = 1330, Female = 97%, Age = 18–40 years.	ISI	8
44	Casagrande et al., 2020 [86]	Italy	No	General Population	Cross-sectional design, N = 2291, Female = 74.6%, Age = 18–50 years.	PSQI	8
45	Cellini et al., 2021 [87]	Italy	No	General Population Children and Adolescents	Cross-sectional design, N = 299, Female = 100%, Age = 40.1 years. Cross-sectional design, N = 299, Female = 46.5%, Age = 8.0 years.	PSQI SDSC	8
46	Cellini et al., 2020 [88]	Italy	Yes	COVID-19 patients	Cross-sectional design, N = 1310, Female = 67.2%, Age = 23.9 years.	PSQI	8
47	Cellini et al., 2021 [89]	Multi	No	General Population	Cross-sectional design, N = 2272, Female = 73.9%, Age = 38.6 years.	PSQI	8
48	Chatterjee et al., 2021 [90]	India	Yes	Healthcare workers [Frontline = 0%, Nurses = 32.9%]	Cross-sectional design, N = 140, Female = 56.7%, Age = 37.7 years.	ISI	7
49	Chen et al., 2021 [91]	China	No	Special Population	Cross-sectional design, N = 834, Female = 100%, Age = NR years.	ISI	8
50	Cheng et al., 2020 [92]	China	No	Healthcare workers [Frontline = 0%, Nurses = 45.88%]	Cross-sectional design, N = 534, Female = 82.4%, Age = 20–50 years.	PSQI	8
51	Cheng et al., 2021b [93]	Multi	No	General Population	Cross-sectional design, N = 2278, Female = 53.5%, Age = NR years.	PROMIS	8
52	Chi et al., 2021 [94]	China	No	Children and Adolescents	Cross-sectional design, N = 1794, Female = 43.9%, Age = 15.3 years.	YSIS	8
53	Chouchou et al., 2021 [95]	France	No	General Population	Cross-sectional design, N = 400, Female = 58.3%, Age = 29.8 years.	PSQI	8
54	Coiro et al., 2021 [96]	Multi	Yes	General Population	Cross-sectional design, N = 2541, Female = 50.2%, Age = 38.7 years.	PSQI	7
55	Cui et al., 2020 [97]	China	No	COVID-19 patients	Cross-sectional design, N = 891, Female = 100%, Age = 18–40 years.	ISI	8
56	Czeisler et al., 2021 [98]	Australia	No	General Population	Cross-sectional design, N = 1531, Female = 48.3%, Age = 38.7 years.	SD	5
57	Dai et al., 2020 [99]	China	No	COVID-19 patients	Cross-sectional design, N = 307, Female = 43.3%, Age = 44–60 years.	PSQI	8
58	Das et al., 2021 [100]	Bangladesh	Yes	General Population	Cross-sectional design, N = 672, Female = 43%, Age = 34.4 years.	PSQI	7
59	Dasdemir et al., 2021 [101]	Turkey	Yes	Special Population	Cross-sectional design, N = 44, Female = 70.5%, Age = 34.3 years.	PSQI	5
60	de Medeiros et al., 2021 [102]	Brazil	Yes	General Population	Cross-sectional design, N = 5, Female = 60%, Age = 40 years.	PSQI	4
61	Demartini et al., 2020 [103]	Italy	No	General Population	Cross-sectional design, N = 432, Female = 72%, Age = 35.9 years.	PSQI	8
62	Du et al., 2021 [104]	Multi	Yes	University Students	Cross-sectional design, N = 2254, Female = 66.6%, Age = 22.5 years.	PSQI	7
63	Duran et al., 2021 [105]	Turkey	No	General Population	Cross-sectional design, N = 405, Female = 70.9%, Age = NR years.	PSQI	8
64	Elhadi et al., 2021 [106]	Libya	Yes	General Population	Cross-sectional design, N = 10,296, Female = 77.6%, Age = 28.9 years.	ISI	6
65	ElHafeez et al., 2021 [107]	Egypt	Yes	General Population Healthcare workers [Frontline = 0%, Nurses = 50%]	Cross-sectional design, N = 538, Female = 66.2%, Age = 35 years. Cross-sectional design, N = 462, Female = 66.2%, Age = 35 years.	PSQI	7
66	Elkholy et al., 2021 [108]	Egypt	No	Healthcare workers [Frontline = 100%, Nurses = 40%]	Cross-sectional design, N = 502, Female = 50%, Age = 20–40 years.	ISI	8
67	Essangri et al., 2021 [109]	Morocco	No	University Students	Cross-sectional design, N = 549, Female = 74%, Age = 22 years.	ISI	8
68	Falkingham et al., 2020 [110]	UK	Yes	General Population	Cross-sectional design, N = 15,360, Female = 53.9%, Age = 36.5 years.	SD	6
69	Fekih-Romdhane et al., 2020 [111]	Tunis	No	Healthcare workers [Frontline = 48.3%, Nurses = 0.65%]	Cross-sectional design, N = 210, Female = 70.5%, Age = 28.6 years.	ISI	8

Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
70	Fidanci et al., 2020 [112]	Turkey	No	Healthcare workers [Frontline = 0%, Nurses = 1%]	Cross-sectional design, N = 153, Female = 67.3%, Age = 33.4 years.	PSQI	7
71	Filippo et al., 2021 [113]	Italy	Yes	Healthcare workers [Frontline = 0%, Nurses = 8.57%]	Cross-sectional design, N = 175, Female = 76.6%, Age = 37 years.	PSQI	5
72	Florin et al., 2020 [114]	France	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 1515, Female = 44.3%, Age = 45.2 years.	ISI	8
73	Franceschini et al., 2020 [115]	Italy	Yes	General Population	Cross-sectional design, N = 6439, Female = 73.1%, Age = 33.9 years.	MOS-SS	8
74	Fu et al., 2020 [116]	China	No	General Population	Cross-sectional design, N = 1242, Female = 69.7%, Age = 18–64 years.	AIS	8
75	Garcia-Priego et al., 2020 [117]	México	Yes	General Population	Cross-sectional design, N = 561, Female = 71%, Age = 30.7 years.	SD	6
76	Garriga-Baraut et al., 2021 [118]	Multi	Yes	Children and Adolescents	Longitudinal design, N = 25, Female = 64%, Age = 14 years.	SDSC	4
77	Gas et al., 2021 [119]	Turkey	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 699, Female = 64.7%, Age = 21.3 years.	PSQI	7
78	Ge et al., 2020 [120]	China	No	University Students	Cross-sectional design, N = 2009, Female = 51%, Age = NR years.	ISI	8
79	Genta et al., 2021 [121]	Brazil	Yes	Children and Adolescents	Longitudinal design, N = 94, Female = 64%, Age = 15 years.	PSQI	6
80	Giardino et al., 2020 [122]	Argentina	No	Healthcare workers [Frontline = 0%, Nurses = 7.5%]	Cross-sectional design, N = 1059, Female = 72.7%, Age = 41.7 years.	ISI	8
81	Goodman-Casanova et al., 2020 [123]	Spain	Yes	Special Population	Cross-sectional design, N = 93, Female = 65%, Age = 73.3 years.	SD	4
82	Goularte et al., 2021 [124]	Brazil	Yes	General Population	Cross-sectional design, N = 1996, Female = 84.5%, Age = 34.2 years.	PSQI	7
83	Gu et al., 2020 [125]	China	No	Healthcare workers [Frontline = 0%, Nurses = 77.9%]	Cross-sectional design, N = 522, Female = 77.6%, Age = 18–40 years.	ISI	8
84	Gualano et al., 2020 [126]	Italy	Yes	General Population	Cross-sectional design, N = 1515, Female = 65.6%, Age = 42 years.	ISI	8
85	Guo et al., 2020 [127]	China	No	General Population	Cross-sectional design, N = 2441, Female = 52.4%, Age = 18–50 years.	PSQI	8
86	Gupta et al., 2020 [128]	India	Yes	General Population Healthcare workers [Frontline = 0%, Nurses = 50%]	Cross-sectional design, N = 579, Female = 37.7%, Age = 38.8 years. Cross-sectional design, N = 379, Female = 46.2%, Age = 35.7 years.	ISI	7
87	Hao et al., 2020 [129]	China	Yes	Special Population	Case-Control design, N = 185, Female = 49.8%, Age = 33 years.	ISI	7
88	Haravuori et al., 2020 [130]	Finland	No	General Population	Longitudinal design, N = 4804, Female = 87.5%, Age = 45 years.	ISI	8
89	He et al., 2020 [131]	China	No	COVID-19 patients General Population Healthcare workers [Frontline = NR %, Nurses = NR%]	Cross-sectional design, N = 1912, Female = 70.1%, Age = 56.8 years. Cross-sectional design, N = 374, Female = 77.4%, Age = 56.8 years. Cross-sectional design, N = 403, Female = 49.6%, Age = 56.8 years.	PSQI	8
90	Hendrickson et al., 2020 [132]	USA	Yes	Healthcare workers [Frontline = 44%, Nurses = 34.59%]	Cross-sectional design, N = 118, Female = NR%, Age = 41 years.	ISI	5
91	Herrero San Martin et al., 2020 [133]	Spain	No	General Population Healthcare workers [Frontline = 58.82%, Nurses = 15.29%]	Cross-sectional design, N = 70, Female = 58.8%, Age = 36.4 years. Cross-sectional design, N = 100, Female = 59%, Age = 36.4 years.	PSQI	7
92	Huang et al., 2020 [134]	China	No	Healthcare workers [Frontline = 100%, Nurses = 100%]	Cross-sectional design, N = 966, Female = 91.2%, Age = 31.9 years.	PSQI	8
93	Huang et al., 2020 [135]	China	No	General Population	Cross-sectional design, N = 1172, Female = 69.3%, Age = 18–40 years.	ISI	8
94	Huang et al., 2020 [136]	China	No	General Population	Cross-sectional design, N = 7236, Female = 54.6%, Age = 36.6 years.	PSQI	8
95	Hussen et al., 2021 [137]	Iraq	Yes	General Population	Cross-sectional design, N = 320, Female = NR%, Age = NR years.	SD	6
96	Idrissi et al., 2020 [138]	Morocco	Yes	General Population	Cross-sectional design, N = 827, Female = 52.2%, Age = 35.9 years.	AIS	8
97	Innocenti et al., 2020 [139]	Italy	Yes	General Population	Cross-sectional design, N = 1035, Female = 82.9%, Age = NR years.	PSQI	7
98	Iqbal et al., 2020 [140]	Qatar	Yes	COVID-19 patients	Cross-sectional design, N = 50, Female = 52%, Age = 39.5 years.	SD	4
99	Jahrami et al., 2020 [141]	Bahrain	No	Healthcare workers [Frontline = 50%, Nurses = 50%]	Cross-sectional design, N = 257, Female = 70%, Age = 40.2 years.	PSQI	8
100	Jain et al., 2020 [142]	India	No	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 512, Female = 44.3%, Age = 18–60 years.	ISI	8
101	Jiang et al., 2021 [143]	China	Yes	Healthcare workers [Frontline = 35.2%, Nurses = 50.2%]	Cross-sectional design, N = 4245, Female = 77.5%, Age = 38 years.	SRSS	8

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Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
102	Jin et al., 2021 [144]	China	Yes	Healthcare workers [Frontline = 0%, Nurses = 50%]	Cross-sectional design, N = 404, Female = NR%, Age = 30–50 years.	PSQI	7
103	Juanjuan et al., 2020 [145]	China	No	Special Population	Cross-sectional design, N = 658, Female = 100%, Age = 40–65 years.	ISI	8
104	Jung et al., 2020 [146]	Germany	Yes	General Population	Cross-sectional design, N = 3545, Female = 83.1%, Age = 41.4 years.	SD	6
105	Kaparounaki et al., 2020 [147]	Greece	Yes	University Students	Cross-sectional design, N = 1000, Female = 68.1%, Age = 22.1 years.	SRSS	7
106	Khaled et al., 2021 [148]	Qatar	No	General Population	Cross-sectional design, N = 1161, Female = 53.2%, Age = NR years.	SCI	8
107	Khalil et al., 2020 [149]	Egypt	No	Children and Adolescents	Cross-sectional design, N = 83, Female = 74.7%, Age = 12.8 years.	PSQI	4
108	Khamis et al., 2020 [150]	Oman	No	Healthcare workers [Frontline = 27.9%, Nurses = 71.6%]	Cross-sectional design, N = 402, Female = 100%, Age = 36.4 years.	SQS	8
109	Khanal et al., 2020 [151]	Nepal	No	Healthcare workers [Frontline = 45.3%, Nurses = 35.2%]	Cross-sectional design, N = 475, Female = 52.6%, Age = 28.2 years.	ISI	8
110	Khoury et al., 2021 [152]	Canada	No	Special Population	Cross-sectional design, N = 303, Female = 100%, Age = 32.1 years.	ISI	8
111	Kilani et al., 2020 [153]	Multi	No	General Population	Cross-sectional design, N = 1723, Female = 46.8%, Age = 34.9 years.	PSQI	8
112	Killgore et al., 2020 [154]	USA	Yes	General Population	Cross-sectional design, N = 1013, Female = 56%, Age = 18–35 years.	ISI	7
113	Kocevska et al., 2020 [155]	Netherlands	Yes	General Population	Cross-sectional design, N = 667, Female = NR%, Age = NR years.	ISI	8
114	Kokou-Kpolou et al., 2020 [156]	France	Yes	General Population	Cross-sectional design, N = 556, Female = 75.5%, Age = 30.1 years.	ISI	7
115	Kolokotroni et al., 2021 [157]	Cyprus	Yes	General Population	Cross-sectional design, N = 745, Female = 73.8%, Age = 39 years.	PSQI	7
116	Lahiri et al., 2021 [158]	India	Yes	General Population	Cross-sectional design, N = 1081, Female = 41.7%, Age = 32 years.	ISI	8
117	Lai et al., 2020 [159]	China	No	Healthcare workers [Frontline = 41.5%, Nurses = 60.8%]	Cross-sectional design, N = 1257, Female = 76.7%, Age = 18–40 years.	ISI	8
118	Lai et al., 2020 [160]	UK	No	University Students	Cross-sectional design, N = 124, Female = 63.7%, Age = NR years.	ISI	6
119	Lavigne-Cerván et al., 2021 [161]	Spain	Yes	Children and Adolescents	Cross-sectional design, N = 1028, Female = 46.5%, Age = 10.5 years.	BEARS	7
120	Li et al., 2021 [162]	Australia	Yes	Children and Adolescents	Cross-sectional design, N = 760, Female = 72%, Age = 14.8 years.	ISI	7
121	Li et al., 2020 [163]	Taiwan	Yes	General Population	Cross-sectional design, N = 1970, Female = 66.2%, Age = 37.8 years.	SD	6
122	Li et al., 2021 [164]	China	Yes	COVID-19 patients	Cross-sectional design, N = 51, Female = 58%, Age = 46.1 years.	PSQI	5
123	Li et al., 2020 [165]	China	Yes	Healthcare workers [Frontline = 23.3%, Nurses = 55.1%]	Cross-sectional design, N = 606, Female = 81.2%, Age = 35.8 years.	ISI	7
124	Li et al., 2021 [166]	China	No	Special Population	Cross-sectional design, N = 1063, Female = 67.4%, Age = 62.8 years.	ISI	8
125	Liang et al., 2020 [167]	China	No	General Population Healthcare workers [Frontline = 100%, Nurses = 50.0%]	Cross-sectional design, N = 1104, Female = 69.5%, Age = 20–60 years. Cross-sectional design, N = 889, Female = 74.8%, Age = 20–60 years.	ISI	8
126	Liguori et al., 2020 [168]	Italy	Yes	COVID-19 patients	Cross-sectional design, N = 103, Female = 42.7%, Age = 55 years.	SNS	5
127	Lin et al., 2021 [169]	China	Yes	General Population	Cross-sectional design, N = 5461, Female = 70.1%, Age = 37.6 years.	ISI	7
128	Liu et al., 2020 [170]	China	Yes	General Population	Cross-sectional design, N = 285, Female = 54.5%, Age = NR years.	PSQI	7
129	Liu et al., 2021 [171]	China	No	Healthcare workers [Frontline = 0%, Nurses = 63.8%]	Cross-sectional design, N = 2126, Female = 97.7%, Age = NR years.	ISI	8
130	Liu et al., 2021 [172]	China	No	General Population	Cross-sectional design, N = 2858, Female = 53.6%, Age = NR years.	PSQI	8
131	Liu et al., 2020 [173]	China	No	Healthcare workers [Frontline = 0%, Nurses = 63.8%]	Cross-sectional design, N = 606, Female = 81.2%, Age = 35.8 years.	ISI	8
132	Liu et al., 2020 [174]	USA	No	General Population	Cross-sectional design, N = 898, Female = 81.3%, Age = 24.5 years.	MOS-SS	8
133	Lu et al., 2020 [175]	China	No	Children and Adolescents	Cross-sectional design, N = 965, Female = 42.4%, Age = 15.3 years.	YSRIS	8
134	Machón et al., 2021 [176]	Spain	Yes	Special Population	Cross-sectional design, N = 38, Female = 71%, Age = 83 years.	EQ-5D-5L	5
135	Magnavita et al., 2020 [177]	Italy	No	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 90, Female = 52.2%, Age = NR years.	SCI	6
136	Majumdar et al., 2021 [178]	India	Yes	General Population University Students	Cross-sectional design, N = 203, Female = 18.2%, Age = 33.1 years. Cross-sectional design, N = 325, Female = 60.9%, Age = 22.1 years.	ESS	6

Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
137	Mandelkorn et al., 2021 [179]	Multi USA	Yes	General Population General Population	Cross-sectional design, N = 2562, Female = 68%, Age = 45.2 years. Cross-sectional design, N = 971, Female = 52.8%, Age = 40.4 years.	PSQI	8
138	Marelli et al., 2020 [180]	Italy	No	University Students	Longitudinal design, N = 400, Female = 75.8%, Age = 29.9 years.	PSQI	8
139	Marroquín et al., 2020 [181]	USA	No	General Population	Cross-sectional design, N = 435, Female = 46.4%, Age = 39.2 years.	ISI	8
140	Martínez-de-Quel et al., 2021 [182]	Spain	No	General Population	Longitudinal design, N = 161, Female = 37%, Age = 35 years.	PSQI	7
141	Martínez-Lezaun et al., 2020 [183]	Spain	Yes	University Students	Cross-sectional design, N = 75, Female = 80.4%, Age = 21.8 years.	PSQI	7
142	Massicotte et al., 2021 [184]	Canada	No	Special Population	Cross-sectional design, N = 36, Female = 100%, Age = 53.6 years.	ISI	6
143	Mazza et al., 2020 [185]	Italy	No	COVID-19 patients	Cross-sectional design, N = 402, Female = 34.4%, Age = 57.8 years.	MOS-SS	8
144	McCall et al., 2020 [186]	USA	No	Healthcare workers [Frontline = 0%, Nurses = 55.5%]	Cross-sectional design, N = 573, Female = 72%, Age = 43.4 years.	SD	6
145	McCracken et al., 2020 [187]	Sweden	No	General Population	Cross-sectional design, N = 1212, Female = 73.8%, Age = 36.1 years.	ISI	8
146	Meo et al., 2021 [188]	Saudi Arabia	Yes	Healthcare workers [Frontline = 71.5%, Nurses = 15.4%]	Cross-sectional design, N = 1678, Female = 51.2%, Age = 34.1 years.	PSQI	7
147	Miaskowski et al., 2020 [189]	USA	Yes	Special Population	Cross-sectional design, N = 187, Female = 97.9%, Age = 63.3 years.	SD	4
148	Mongkhon et al., 2021 [190]	Thailand	Yes	General Population	Cross-sectional design, N = 4004, Female = 65.4%, Age = 29.1 years.	ISI	8
149	Murata et al., 2020 [191]	USA	Yes	Children and Adolescents General Population	Cross-sectional design, N = 583, Female = 80%, Age = 15.8 years. Cross-sectional design, N = 4326, Female = 80%, Age = 43.6 years.	SD	5
150	Necho et al., 2020 [192]	Ethiopia	No	Special Population	Cross-sectional design, N = 423, Female = 40.7%, Age = 36.7 years.	ISI	8
151	Osiogo et al., 2021 [193]	Canada	Yes	General Population	Cross-sectional design, N = 6041, Female = 86.8%, Age = 20–60 years.	SD	6
152	Ozluk et al., 2021 [194]	Turkey	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 347, Female = 24.2%, Age = 20–65 years.	ISI	7
153	Parlapani et al., 2020 [195]	Greece	No	Special Population	Cross-sectional design, N = 103, Female = 61.2%, Age = 69.9 years.	AIS	6
154	Pedrozo-Pupo et al., 2020 [196]	Colombia	No	Special Population	Cross-sectional design, N = 292, Female = 64.7%, Age = 60.4 years.	AIS	8
155	Petrov et al., 2021 [197]	Multi	Yes	General Population	Cross-sectional design, N = 991, Female = 72.5%, Age = 37.9 years.	ISI	8
156	Pieh et al., 2020 [198]	Austria	Yes	General Population	Cross-sectional design, N = 1005, Female = 52.7%, Age = 18–65 years.	ISI	8
157	Poyraz et al., 2020 [199]	Turkey	No	COVID-19 patients	Cross-sectional design, N = 284, Female = 49.8%, Age = 39.7 years.	PSQI	8
158	Qi et al., 2020 [200]	China	No	Healthcare workers [Frontline = 61.33%, Nurses = 0%]	Cross-sectional design, N = 1306, Female = 80.4%, Age = 33.1 years.	PSQI, ISI	8
159	Que et al., 2020 [201]	China	No	Healthcare workers [Frontline = 0%, Nurses = 9.1%]	Cross-sectional design, N = 2285, Female = 69.1%, Age = 31.1 years.	ISI	8
160	Ren et al., 2020 [202]	China	No	General Population	Cross-sectional design, N = 1172, Female = 69.3%, Age = 22 years.	ISI	8
161	Repon et al., 2021 [203]	Bangladesh	Yes	Healthcare workers [Frontline = 0%, Nurses = 26%]	Cross-sectional design, N = 355, Female = 43%, Age = 20–60 years.	PSQI	7
162	Robillard et al., 2020 [204]	Canada	Yes	General Population	Cross-sectional design, N = 5525, Female = 67.1%, Age = 55.6 years.	PSQI	8
163	Rossi et al., 2020 [205]	Italy	No	General Population Healthcare workers [Frontline = 52.1%, Nurses = 36%]	Case-control design, N = 21,342, Female = 80.4%, Age = 38.95 years. Case-control design, N = 2706, Female = 79.5%, Age = 42 years.	ISI ISI	8
164	Rossi et al., 2020 [206]	Italy	No	General Population	Cross-sectional design, N = 18,147, Female = 79.5%, Age = 38 years.	ISI	8
165	Roy et al., 2020 [207]	India	Yes	General Population	Cross-sectional design, N = 662, Female = 51.2%, Age = 29 years.	SD	6
166	Saadeh et al., 2021 [208]	Jordan	Yes	University Students	Cross-sectional design, N = 6157, Female = 71.3%, Age = 19.8 years.	PSQI	8
167	Sadeghniiat-Haghighi et al., 2021 [209]	Iran	No	General Population	Cross-sectional design, N = 1223, Female = 67.6%, Age = 39.8 years.	ISI	7
168	Sagaon-Teyssier et al., 2020 [210]	Mali	Yes	Healthcare workers [Frontline = 0%, Nurses = 14.8%]	Cross-sectional design, N = 135, Female = 39.3%, Age = 40 years.	ISI	5
169	Sagherian et al., 2020 [211]	USA	No	Healthcare workers [Frontline = 63.2%, Nurses = 100%]	Cross-sectional design, N = 564, Female = 94.1%, Age = 18–40 years.	ISI	8

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Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
170	Saguem et al., 2021 [212]	Tunis	Yes	University Students	Cross-sectional design, N = 251, Female = 82.5%, Age = 21 years.	PSQI	8
171	Şahin et al., 2020 [213]	Turkey	No	Healthcare workers [Frontline = 60.6%, Nurses = 27.1%]	Cross-sectional design, N = 939, Female = 66%, Age = 18–40 years.	ISI	8
172	Salfi et al., 2021 [214]	Italy	Yes	General Population	Cross-sectional design, N = 13,989, Female = 77.6%, Age = 34.8 years.	PSQI, ISI	8
173	Sañudo et al., 2020 [215]	Spain	No	General Population	Cross-sectional design, N = 20, Female = 47%, Age = 22.6 years.	PSQI	5
174	Saracoglu et al., 2020 [216]	Turkey	No	Healthcare workers [Frontline = 0%, Nurses = 67.3%]	Cross-sectional design, N = 208, Female = 27.9%, Age = 29 years.	PSQI	7
175	Saraswathi et al., 2020 [217]	India	No	University Students	Longitudinal design, N = 217, Female = 64%, Age = 20 years.	PSQI	7
176	Scotta et al., 2020 [218]	Argentina	Yes	University Students	Cross-sectional design, N = 584, Female = 81%, Age = 22.5 years.	ISI	8
177	Sekartaji et al., 2021 [219]	Indonesia	Yes	University Students	Cross-sectional design, N = 101, Female = 58.4%, Age = 21–26 years.	ISI	4
178	Sharma et al., 2020 [220]	Nepal	Yes	General Population	Cross-sectional design, N = 204, Female = 32.8%, Age = 32 years.	SD	5
179	Sharma et al., 2020 [221]	India	No	Healthcare workers [Frontline = 60.9%, Nurses = 41.8%]	Cross-sectional design, N = 184, Female = 58.7%, Age = 20–50 years.	ISI	7
180	Sharma et al., 2021 [222]	India	Yes	Healthcare workers [Frontline = 0%, Nurses = 0%]	Cross-sectional design, N = 100, Female = 0%, Age = 30–60 years.	SQS	4
181	Shi et al., 2020 [223]	China	No	General Population	Cross-sectional design, N = 56,679, Female = 52.1%, Age = 36 years.	ISI	8
182	Shillington et al., 2021 [224]	Canada	Yes	General Population	Cross-sectional design, N = 2192, Female = 89.6%, Age = 43 years.	PSQI	7
183	Simonetti et al., 2021 [225]	Italy	Yes	Healthcare workers [Frontline = 80.8%, Nurses = 100%]	Cross-sectional design, N = 1005, Female = 65.9%, Age = 40.2 years.	PSQI	7
184	Song et al., 2020 [226]	China	No	General Population	Cross-sectional design, N = 709, Female = 74.2%, Age = 35.4 years.	ISI	8
185	Stanton et al., 2020 [227]	Australia	Yes	General Population	Cross-sectional design, N = 1491, Female = NR%, Age = NR years.	SD	6
186	Stewart et al., 2021 [228]	USA	Yes	Healthcare workers [Frontline = 100%, Nurses = 0%]	Cross-sectional design, N = 963, Female = 73.4%, Age = 18–50 years.	PSQI, ISI	7
187	Sun et al., 2020 [229]	China	Yes	General Population	Cross-sectional design, N = 2091, Female = 60.8%, Age = 16–60 years.	SD	6
188	Sunil et al., 2021 [230]	India	No	Healthcare workers [Frontline = 0%, Nurses = 47.6%]	Cross-sectional design, N = 313, Female = 35.5%, Age = 21–61 years.	ISI	8
189	Tan Wanqiu et al., 2020 [231]	China	No	Healthcare workers [Frontline = NR %, Nurses = NR%]	Cross-sectional design, N = 673, Female = 25.6%, Age = 30.8 years.	ISI	8
190	Tang et al., 2020 [232]	China	Yes	University Students	Cross-sectional design, N = 2485, Female = 60.8%, Age = 19.8 years.	SD	6
191	Than et al., 2020 [233]	Vietnam	No	Healthcare workers [Frontline = 100%, Nurses = 63%]	Cross-sectional design, N = 173, Female = 68.2%, Age = 31 years.	ISI	7
192	Tiete et al., 2020 [234]	Belgium	Yes	Healthcare workers [Frontline = 50.4%, Nurses = 72.3%]	Cross-sectional design, N = 647, Female = 78.4%, Age = 20–50 years.	ISI	7
193	Totskiy et al., 2021 [235]	Russia	Yes	University Students	Cross-sectional design, N = 39, Female = 64.1%, Age = 20.6 years.	ISI	5
194	Trabelsi et al., 2021a [236]	Multi	Yes	General Population	Longitudinal design, N = 517, Female = 52.2%, Age = 63.2 years.	PSQI	7
195	Trabelsi et al., 2021b [237]	Multi	No	General Population	Longitudinal design, N = 5056, Female = 59.4%, Age = 18–55 years.	PSQI	8
196	Tselebis et al., 2020 [238]	Greece	No	Healthcare workers [Frontline = 0%, Nurses = 100%]	Cross-sectional design, N = 150, Female = 80%, Age = 42.3 years.	AIS	7
197	Tu et al., 2020 [239]	China	No	Healthcare workers [Frontline = 100%, Nurses = 100%]	Cross-sectional design, N = 100, Female = 100%, Age = 34.4 years.	PSQI	6
198	Varma et al., 2021 [240]	Multi	Yes	General Population	Cross-sectional design, N = 1653, Female = 67.7%, Age = 42.9 years.	PSQI	8
199	Vitale et al., 2020 [241]	Italy	Yes	COVID-19 patients	Cross-sectional design, N = 4, Female = 25%, Age = 54 years.	PSQI	4
200	Voitaidis et al., 2020 [242]	Greece	Yes	General Population	Cross-sectional design, N = 2427, Female = 76.2%, Age = 18–30 years.	AIS	7
201	Wang et al., 2021a [243]	China	Yes	General Population COVID-19 patients	Case-control design, N = 1743, Female = 47.8%, Age = 32.7 years. Case-control design, N = 1674, Female = 49.8%, Age = 32.6 years.	ISI	7
202	Wang et al., 2020 [244]	China	Yes	Healthcare workers [Frontline = 50%, Nurses = 59.2%]	Cross-sectional design, N = 274, Female = 77.4%, Age = 37 years.	PSQI	7
203	Wang et al., 2021 [245]	China	Yes	Children and Adolescents	Cross-sectional design, N = 11,072, Female = 47.9%, Age = 11.5 years.	SD	6
204	Wang et al., 2020 [246]	China	No	General Population	Cross-sectional design, N = 19,372, Female = 52%, Age = 11–87 years.	ISI	8
205	Wang et al., 2021 [247]	China	No	General Population	Cross-sectional design, N = 5676, Female = 71.4%, Age = NR years.	ISI	8

Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
206	Wang et al., 2020 [248]	China	No	General Population	Cross-sectional design, N = 4191, Female = 62%, Age = 36.2 years.	ISI	8
207	Wang et al., 2020 [249]	China	No	University Students	Cross-sectional design, N = 3092, Female = 66.4%, Age = NR years.	SRSS	8
208	Wang et al., 2020 [250]	China	No	COVID-19 patients	Cross-sectional design, N = 484, Female = 50.2%, Age = 52.5 years.	ISI	8
209	Wang et al., 2020 [251]	China	No	General Population	Cross-sectional design, N = 6437, Female = 56.1%, Age = 31.5 years.	PSQI	8
210	Wang et al., 2020 [252]	China	No	Healthcare workers [Frontline = 33%, Nurses = 0%]	Cross-sectional design, N = 2001, Female = 64.5%, Age = 33 years.	PSQI	8
211	Wang et al., 2020 [253]	China	No	Healthcare workers [Frontline = 0%, Nurses = 61%]	Cross-sectional design, N = 123, Female = 90%, Age = 33.8 years.	PSQI	6
212	Wańkowicz et al., 2020 [254]	Poland	No	Healthcare workers [Frontline = 46.7%, Nurses = 0%]	Cross-sectional design, N = 441, Female = 52.2%, Age = 40 years.	ISI	8
213	Wańkowicz et al., 2020 [255]	Poland	No	Special Population	Case-control design, N = 723, Female = 54.4%, Age = 39.1 years.	ISI	8
214	Wasim et al., 2020 [256]	Pakistan	No	Healthcare workers [Frontline = 0%, Nurses = 20.8%]	Cross-sectional design, N = 356, Female = 52%, Age = NR years.	ISI	8
215	Windiani et al., 2021 [257]	Indonesia	No	Children and Adolescents	Cross-sectional design, N = 204, Female = 48.5%, Age = 16 years.	PSQI	4
216	Wu et al., 2020 [258]	China	No	Healthcare workers [Frontline = 100%, Nurses = 0%]	Case-control design, N = 120, Female = 74.2%, Age = 33.7 years.	PSQI	6
217	Xia et al., 2021 [259]	China	No	Special Population	Case-control design, N = 288, Female = 54.8%, Age = 60.5 years.	PSQI	8
218	Xu et al., 2021 [260]	China	Yes	Special Population	Cross-sectional design, N = 274, Female = 100%, Age = 30.4 years.	PSQI	7
219	Yadav et al., 2021 [261]	India	Yes	COVID-19 patients	Cross-sectional design, N = 100, Female = 27%, Age = 42.9 years.	PSQI	5
220	Yang et al., 2020 [262]	China	Yes	General Population	Cross-sectional design, N = 2410, Female = 49.2%, Age = 36.3 years.	PSQI	7
221	Yang et al., 2020 [263]	China	No	General Population Healthcare workers [Frontline = 100%, Nurses = 84.4%]	Case-control design, N = 15,000, Female = 57.1%, Age = NR years. Case-control design, N = 1036, Female = 72.9%, Age = 20–50 years.	ISI	8
222	Yang et al., 2021 [264]	China	No	Healthcare workers [Frontline = 100%, Nurses = 84.4%]	Cross-sectional design, N = 1036, Female = 72.9%, Age = 20–50 years.	ISI	8
223	Yifan et al., 2020 [265]	China	Yes	Healthcare workers [Frontline = 100%, Nurses = 100%]	Cross-sectional design, N = 140, Female = 84.3%, Age = 29.4 years.	SD	5
224	Yitayih et al., 2020 [266]	Ethiopia	No	Healthcare workers [Frontline = 0%, Nurses = 52.2%]	Cross-sectional design, N = 249, Female = 52.6%, Age = 27.4 years.	ISI	7
225	Youssef et al., 2020 [267]	Egypt	No	Healthcare workers [Frontline = 10.2%, Nurses = 9.1%]	Cross-sectional design, N = 540, Female = 45.6%, Age = 37.3 years.	ISI	8
226	Yu et al., 2020 [268]	China	Yes	General Population	Cross-sectional design, N = 1138, Female = 65.6%, Age = NR years.	ISI	8
227	Yuksel et al., 2021 [269]	Multi	Yes	General Population	Cross-sectional design, N = 6882, Female = 78.8%, Age = 42.3 years.	SD	6
228	Zanghì et al., 2020 [270]	Italy	No	Special Population	Cross-sectional design, N = 432, Female = 64.1%, Age = 40.4 years.	ISI	8
229	Zhan et al., 2020 [271]	China	No	Healthcare workers [Frontline = 100%, Nurses = 100%]	Cross-sectional design, N = 1794, Female = 97%, Age = 25–65 years.	AIS	8
230	Zhang et al., 2020 [272]	China	Yes	General Population	Cross-sectional design, N = 2027, Female = 61.2%, Age = 35.5 years.	PSQI	7
231	Zhang et al., 2021 [273]	China	Yes	COVID-19 patients	Cross-sectional design, N = 205, Female = 48.3%, Age = 58 years.	PSQI	5
232	Zhang et al., 2020 [274]	China	Yes	Healthcare workers [Frontline = 0%, Nurses = 11.3%]	Cross-sectional design, N = 2182, Female = 64.2%, Age = NR years.	ISI	7
233	Zhang et al., 2020 [275]	China	No	COVID-19 patients	Cross-sectional design, N = 135, Female = 42.2%, Age = 63 years.	PSQI	6
234	Zhang et al., 2021 [276]	China	No	Healthcare workers [Frontline = 100%, Nurses = 46.7%]	Cross-sectional design, N = 319, Female = 62.1%, Age = 30.4 years.	PSQI	8
235	Zhang et al., 2021 [277]	China	No	Special Population	Cross-sectional design, N = 456, Female = 100%, Age = NR years.	PSQI	8
236	Zhang et al., 2020 [278]	China	No	Healthcare workers [Frontline = 28.6%, Nurses = 55.7%]	Cross-sectional design, N = 524, Female = 74.4%, Age = 34.9 years.	ISI	8
237	Zhang et al., 2020 [279]	China	No	COVID-19 patients	Cross-sectional design, N = 30, Female = 50%, Age = 42.5 years.	ISI	6
238	Zhang et al., 2020 [280]	China	No	General Population	Cross-sectional design, N = 3237, Female = 47.1%, Age = NR years.	ISI	8
239	Zhang et al., 2020 [281]	China	No	Healthcare workers [Frontline = 50%, Nurses = 62.9%]	Cross-sectional design, N = 1563, Female = 82.7%, Age = 18–60 years.	ISI	8
240	Zhang et al., 2020 [282]	China	No	University Students	Longitudinal design, N = 66, Female = 62.1%, Age = 20.7 years.	PSQI	6

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Table 1 (*continued*)

ID	Authors, year (Ref.)	Country	Lockdown Period	Population	Methodology	Measures[a]	Quality score[b]
241	Zhao et al., 2020 [283]	China	Yes	Healthcare workers [Frontline = 100%, Nurses = 46%]	Cross-sectional design, N = 215, Female = 76.2%, Age = 35.9 years.	PSQI	5
242	Zheng et al., 2020 [284]	China	Yes	Healthcare workers [Frontline = 63.77%, Nurses = 74.88%]	Cross-sectional design, N = 207, Female = 84.5%, Age = 37 years.	PSQI	5
243	Zheng et al., 2021 [285]	China	Yes	General Population	Cross-sectional design, N = 631, Female = 61.2%, Age = 21.1 years.	PSQI	7
244	Zhou et al., 2020 [286]	China	Yes	Children and Adolescents	Cross-sectional design, N = 11,835, Female = 57.7%, Age = 17.4 years.	PSQI	7
245	Zhou et al., 2020 [287]	China	No	General population Healthcare workers [Frontline = 100%, Nurses = NR %]	Case-control design, N = 1099, Female = 69.4%, Age = 28.3 years. Case-control design, N = 606, Female = 81.2%, Age = 35.8 years.	ISI	8
246	Zhou et al., 2020 [288]	China	No	Healthcare workers [Frontline = 100%, Nurses = 83.6%]	Cross-sectional design, N = 1931, Female = 95.4%, Age = 35.1 years.	PSQI	8
247	Zhou et al., 2020 [289]	China	No	Special Population	Cross-sectional design, N = 859, Female = 100%, Age = 33.3 years.	ISI	8
248	Zhuo et al., 2020 [290]	China	No	Healthcare workers [Frontline = 100%, Nurses = NR %]	Cross-sectional design, N = 26, Female = 46.2%, Age = 41.9 years.	ISI	5
249	Zreik et al., 2021 [291]	Israel	Yes	General Population Children and Adolescents	Cross-sectional design, N = 264, Female = 100%, Age = 34 years Cross-sectional design, N = 264, Female = 54.4%, Age = 0.5 years.	ISI BICQ	7
250	Zupancic et al., 2021 [292]	Slovenia	Yes	Healthcare workers [Frontline = 27.03%, Nurses = NR%]	Cross-sectional design, N = 1019, Female = 73.3%, Age = NR years.	ESS	8

[a] Measures: AIS = Athens insomnia scale. BEARS = Bedtime issues, excessive daytime sleepiness, night awakenings, regularity and duration of sleep, and snoring. ISI = Insomnia severity index. MOS-SS = Medical outcomes study sleep scale. MSQ = Mini sleep questionnaire. PROMIS = Patient-reported outcomes measurement information system-sleep disturbance. PSQI = Pittsburgh sleep quality index. SCI = Sleep condition indicator. SCI-02 = Sleep condition indicator-02. SD = Self-developed. SDSC = Bruni scale/sleep disturbance scale for children. SNS = Subjective neurological symptoms. SQS = Sleep quality scale. SRSS = Self-rating scale of sleep. YSIS = Youth self-rating insomnia scale.

[b] The Newcastle−Ottawa Scale (NOS) was used to evaluate the methodological quality and assess the risk of bias of the studies included in the current review. The look at three aspects (participants selection, comparability, and outcome and statistics).

a higher risk of sleep disturbances in university students and special populations P = 0.04 and P = 0.05, respectively. Detailed results are presented in Table 2.

For the healthcare workers population, being a nurse or frontline or a nurse working in frontline (interaction term) was not a moderator of the size of sleep disturbances during the pandemic COVID-19 P = 0.15, P = 0.78, and P = 0.98, respectively.

Assessment of sleep disturbances during COVID-19 by used measure

Random-effects subgroup meta-analysis of sleep disturbances doing the COVID-19 pandemic by research measure used showed statistically different results between the groups Q = 51.81 (3), P = 0.001. The largest magnitude of sleep disturbances (poor sleep quality) was obtained by studies that have used the PSQI, K = 114 studies and yielded a prevalence rate of 51.87% [47.87; 55.84%],

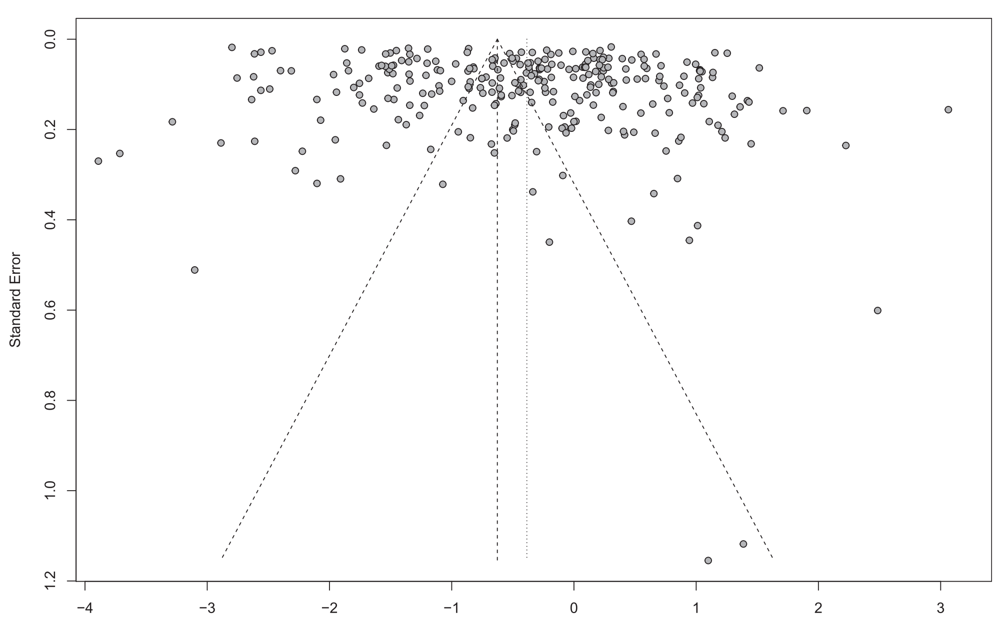

Fig. 3. Funnel plot of sleep disturbances (all populations, all countries, all measures).

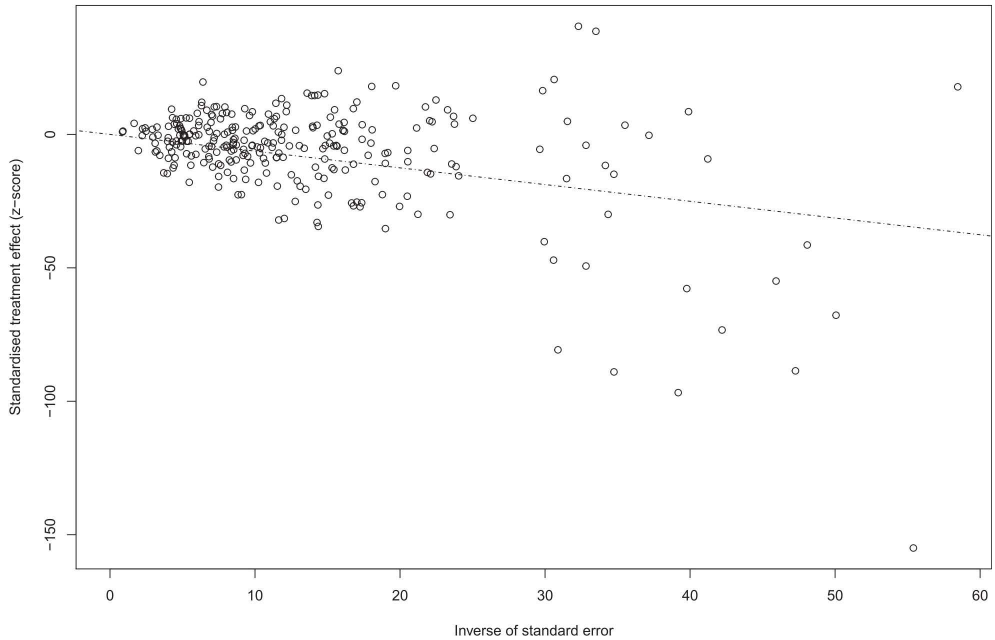

Fig. 4. Radial plot of sleep disturbances (all populations, all countries, all measures).

$\tau^2 = 0.73$, $I^2 = 99.40\%$. ISI (moderate to severe insomnia) was used in K = 110 studies and yielded a prevalence rate of 30.98% [26.77; 35.54%], $\tau^2 = 1.19$, $I^2 = 99.7\%$. AIS (insomnia) was used in K = 12 studies and yielded a prevalence rate of 47.22% [41.37; 53.15%], $\tau^2 = 0.16$, $I^2 = 96.9\%$. Finally, other measures were used in K = 49 studies and yielded a prevalence rate 35.70% [30.38; 41.39%], $\tau^2 = 0.72$, $I^2 = 99.6\%$.

Moderator analysis revealed that neither age (older age) nor sex (larger proportion of female) was associated with higher rates of sleep disturbances using any research measure.

Publication bias was detected in the studies that have used ISI and adjusted prevalence rate of sleep disturbances with K = 147 (with 37 added studies) is 18.38% [15.36; 21.85%], $\tau^2 = 1.76$ [1.58; 2.75], $\tau = 1.32$ [1.25; 1.66], $I^2 = 99.8\%$; H = 21.36 [20.99; 21.73], Q = 66,590 (146), P = 0.001. Detailed results are presented in Table 2, and Fig. S10.

Assessment of sleep disturbances during COVID-19 by lockdown status

About half the studies 123 (49.2%) collected data during no lockdown period and about 162 (64.8%) collected data during a local lockdown. Results for subgroups based on lockdown status using random-effects modelling showed that the prevalence rate of sleep disturbances during lockdown periods was higher 42.49% [38.21; 46.89%], $\tau^2 = 1.31$, $I^2 = 99.8\%$ compared to periods of non-lockdown 37.97% [34.42; 41.66%], $\tau^2 = 0.74$, $I^2 = 99.4\%$. Test for subgroup differences showed that between groups differences did not reach statistical significance Q = 2.45 (1), P = 0.11. Detailed results are presented in Table 2, and Fig. S11.

Assessment of sleep disturbances during COVID-19 by year of publication

Papers published in 2021 reported a higher prevalence rate of sleep disturbances compared to papers published in 2020. The overall rate of sleep disturbances during COVID-19 pandemic in 2021 was 47.14% [43.01; 51.30%], $\tau^2 = 0.80$, $I^2 = 99.6\%$. In 2020 the rate was lower with an overall prevalence of 36.20% [3252; 40.04%], $\tau^2 = 1.16$, $I^2 = 99.7\%$. Test for subgroup differences between groups indicated that the difference is statistically significant Q = 14.42 (1), P = 0.001. Detailed results are presented in Table 2 and Fig. S12.

Assessment of sleep disturbances during COVID-19 by research design

Most 249 (87.4%) of the data were collected using a cross-sectional design; on the other hand, 25 (8.8) were collected using longitudinal designs, and only 11 (3.8%) were collected using case–control studies. The overall pooled prevalence rate obtained by longitudinal studies was the highest, 48.36% [43.14; 53.61%], $\tau^2 = 0.25$ [0.28; 1.26], $\tau = 0.51$ [0.50; 1.12, $I^2 = 98.0\%$ [97.5%; 98.3%], H = 6.98 [6.37; 7.66], Q = 1171 (24), P = 0.001. Results obtained by cross-sectional studies followed, 40.26% [37.10; 43.49%], $\tau^2 = 1.12$ [0.86; 1.34], $\tau = 1.06$ [0.92; 1.15], $I^2 = 99.7\%$; H = 17.93 [17.66; 18.20], Q = 79,698 (248), P = 0.001. Case-control studies produced the lowest overall prevalence rate of sleep disturbances during the COVID-19 pandemic with an overall rate of 31 57% [18.23; 48.85%], $\tau^2 = 1.50$ [0.58; 4.33], $\tau = 1.22$ [0.76; 2.08], $I^2 = 99.7\%$ [99.7%; 99.8%], H = 18.99 [17.68; 20.40], Q = 3606 (10), P = 0.001. Sex (larger proportion of female sex) was a statistically significant moderator in longitudinal studies P = 0.001. Detailed results are presented in Table 2, and Fig. S13.

Assessment of sleep disturbances during COVID-19 by methodological quality/risk of bias

Studies of moderate and low quality produced similar results, while studies of high quality produced a lower overall rate of sleep disturbances. Specifically, low quality studies K = 10, N = 852 showed an overall rate of sleep disturbances of 42.60% [29.20; 57.19%], $\tau^2 = 0.7182$ [0.34; 3.56], $\tau = 0.84$ [0.58; 1.88], $I^2 = 91.8\%$ [87.1%; 94.8%], H = 3.50 [2.79; 4.40], Q = 110 (9), P = 0.001. Medium quality studies K = 138, N = 144,345 showed an overall rate of sleep disturbances of 46.49% [42.64; 50.39%], $\tau^2 = 0.84$ [0.74; 1.36], $\tau = 0.92$ [0.86; 1.16], $I^2 = 99.4\%$; H = 13.01 [12.68; 13.34], Q = 23,172 (137), P = 0.001. Finally, high quality studies K = 137, N = 348,278 showed an overall rate of sleep disturbances of 34.59% [30.58;

Table 2
Sleep disturbances during COVID-19: a meta-analysis, a moderator analysis and assessment of heterogeneity.

Component	K	N	Random-effects meta-analysis		Heterogeneity					Moderators		Publication Bias	Adjusted results [95%CI]
			Pooled results [95%CI]	Forest Plot	I^2	H	τ^2	Q (Within)	Q (Between)	Age	Sex (%Female)		
Global assessment of sleep disturbances during COVID-19													
Sleep disturbances (all populations, all countries, all measures[a])	285	493,475	40.49% [37.56; 43.48%]	Fig. S2.	99.7%	17.52	1.09	87,213 (284)	NA	0.15	0.92	Egger's P = 0.001	30.50% [27.93; 33.19%]
Assessment of sleep disturbances during COVID-19 by country													
Sleep disturbances (all populations, all measures) China	84	223,196	30.32% [26.26; 34.72%]	Fig. S8.	99.7%	17.45	0.86	25,281 (83)	54 (7) P = 0.001	0.02	0.14	Egger's P = 0.003	20.14% [17.02; 23.65%]
Sleep disturbances (all populations, all measures) Italy	34	91,878	38.64% [28.86; 49.44%]		99.8%	23.99	1.67	18,997 (33)		0.66	0.19	NS	NI
Sleep disturbances (all populations, all measures) India	16	5842	27.25% [19.00; 37.43%]		98.2%	7.39	0.89	819 (15)		0.89	0.78	NS	NI
Sleep disturbances (all populations, all measures) USA	15	13,022	50.21% [41.06; 59.35%]		98.8%	9.18	0.52	1181 (14)		0.35	0.83	NS	NI
Sleep disturbances (all populations, all measures) Turkey	12	5389	44.18% [33.41; 55.53%]		98.0%	7.03	0.62	543 (11)		0.10	0.83	Egger's P = 0.03	60.67% [49.31; 70.98%]
Sleep disturbances (all populations, all measures) Spain	10	1848	58.59% [47.64; 68.76%]		92.8%	3.72	0.45	124 (9)		0.04	0.66	NS	NI
Sleep disturbances (all populations, all measures) Saudi Arabia	10	7197	51.10% [36.67; 65.35%]		99.2%	11.17	0.90	1122 (9)		0.19	0.39	NS	NI
Sleep disturbances (all populations, all measures) all other countries	104	145,103	47.69% [43.67; 51.75%]		99.5%	14.04	0.69	20,316 (103)		0.85	0.78	NS	NI
Assessment of sleep disturbances during COVID-19 by population													
Sleep disturbances (general population, all measures)	121	364,060	36.73% [32.32; 41.38%]	Fig. S9.	99.8%	23.17	1.18	64,436 (120)	9 (5) P = 0.10	0.12	0.34	NS	NI
Sleep disturbances (healthcare workers, all measures)	90	63,685	42.47% [37.95; 47.12%]		99.1%	0.47	0.81	9749 (89)		0.03	0.74	NS	NI
Sleep disturbances (COVID-19 patients, all measures)	16	6821	52.39% [41.69; 62.88%]		98.1%	7.31	0.70	802 (15)		0.60	0.34	Egger's P = 0.006	33.20% [24.17; 43.66%]
Sleep disturbances (university students, all measures)	22	21,880	41.16% [28.76; 54.79%]		99.6%	16.08	1.69	5432 (21)		0.52	0.04	NS	NI
Sleep disturbances (special populations, all measures)	23	8023	41.50% [32.98; 50.56%]		98.1%	7.19	0.77	1136 (22)		0.10	0.05	NS	NI
Sleep disturbances (children and adolescents, all measures)	13	29,006	45.96% [36.90; 55.30%]		99.3%	12.29	0.45	1812 (12)		0.64	0.15	NS	NI
Assessment of sleep disturbances during COVID-19 by used measure													
Sleep disturbances (all populations, PSQI only)	114	134,177	51.87% [47.87; 55.84%]	Fig. S10.	99.4%	13.11	0.73	19,414 (113)	52 (3) P = 0.001	0.76	0.78	NS	NI
Sleep disturbances (all populations, ISI only)	110	256,673	30.98% [26.77; 35.54%]		99.7%	18.39	1.19	36,874 (109)		0.69	0.56	Kendall's P = 0.04 Egger's P = 0.01	18.38% [15.36; 21.85%]
Sleep disturbances (all populations, AIS only)	12	10,169	47.22% [41.37; 53.15%]		96.9%	5.69	0.17	356 (11)		0.45	0.09	NS	NI
Sleep disturbances (all populations, other measures)	49	92,456	35.70% [30.38; 41.39%]		96.9%	16.00	0.72	12,294 (48)		0.054	0.055	NS	NI

Assessment of sleep disturbances during COVID-19 by lockdown status													
Sleep disturbances (all populations, all measures, no lockdown)	123	325,653	37.97% [34.42; 41.66%]	Fig. S11.	99.4%	13.13	0.74	21,033 (122)	3 (1) P = 0.1	0.008	0.51	Egger's P = 0.001	26.68% [23.59; 30.01%]
Sleep disturbances (all populations, all measures, during lockdown)	162	166,275	42.49% [38.21; 46.89%]		99.8%	20.33	1.31	65,459 (161)		0.78	0.39	Kendall's P = 0.03 Egger's P = 0.03	33.01% [29.20; 37.06%]
Assessment of sleep disturbances during COVID-19 by year of publication													
Sleep disturbances (all populations, all measures, 2020)	171	321,988	36.20% [32.52; 40.04%]	Fig. S12.	99.7%	17.55	1.16	52,374 (170)	15 (1) P = 0.001	0.04	0.99	Kendall's P = 0.01 Egger's P = 0.001	23.54% [20.68; 26.66%]
Sleep disturbances (all populations, all measures, 2021)	114	171,487	47.14% [43.01; 51.30%]		99.6%	15.34	0.80	26,601 (113)		0.90	0.56	NS	NI
Assessment of sleep disturbances during COVID-19 by research design													
Sleep disturbances assessed using cross-sectional design	249	445,950	40.26% [37.10; 43.49%]	Fig. S13.	99.7%	17.93	1.12	79,699 (248)	8 (2) P = 0.01	0.15	0.66	Egger's P = 0.002	29.65% [26.91; 32.54%]
Sleep disturbances assessed using case–control design	11	24,820	31.57% [18.23; 48.85%]		99.7%	18.99	1.50	3607 (10)		0.15	0.39	NS	NI
Sleep disturbances assessed using longitudinal design	25	22,705	48.36% [43.14; 53.61%]		98.0%	6.98	0.26	1171 (24)		0.37	0.001	NS	NI
Assessment of sleep disturbances during COVID-19 by methodological quality													
High quality (low risk of bias)	137	348,278	34.59% [30.58; 38.83%]	Fig. S14.	99.8%	21.01	1.18	60,013 (136)	16 (2) P = 0.001	0.59	0.94	Egger's P = 0.049	21.80% [18.56; 25.43%]
Moderate quality (moderate risk of bias)	138	144,345	46.49% [42.64; 50.39%]		99.4%	13.01	0.85	23,172 (137)		0.06	0.27	Egger's P = 0.04	30.50% [27.93; 33.19%]
Low quality (high risk of bias)	10	852	42.60% [29.20; 57.19%]		91.8%	3.50	0.72	110 (9)		0.93	0.58	NS	NI

Abbreviations: CI, Confidence interval. K = denotes the number of studies. N = denotes the number of participants. NA = Not applicable. NI = Not indicated. NS = Not Significant.
Methodological details.
I^2 statistic describes the percentage of variation across studies due to heterogeneity rather than chance.
In a random-effects meta-analysis, the extent of variation among the effects observed in different studies (between-study variance) is referred to as τ-squared.
Cochran's Q, which is calculated as the weighted sum of squared differences between individual study effects and the pooled effect across studies, with the weights being those used in the pooling method.
Meta-regression was performed using Method of Moments Estimator for Random Effect Multivariate Meta-Analysis.
Publication bias was not observed in the Funnel plot.
Adjusted results were calculated using trill-and-fill.

[a] Measures: AIS = Athens insomnia scale. BEARS = Bedtime issues, excessive daytime sleepiness, night awakenings, regularity and duration of sleep, and snoring. ISI = Insomnia severity index. MOS-SS = Medical outcomes study sleep scale. MSQ = Mini sleep questionnaire. PROMIS = Patient-reported outcomes measurement information system-sleep disturbance. PSQI = Pittsburgh sleep quality index. SCI = Sleep condition indicator. SCI-02 = Sleep condition indicator-02. SD = Self-developed. SDSC = Bruni scale/sleep disturbance scale for children. SNS = Subjective neurological symptoms. SQS = Sleep quality scale. SRSS = Self-rating scale of sleep. YSIS = Youth self-rating insomnia scale.

38.83%], $\tau^2 = 1.17$ [0.78; 1.37], $\tau = 1.08$ [0.88; 1.17], $I^2 = 99.8\%$; H = 21.01 [20.63; 21.39], Q = 60,013 (136), P = 0.001. Detailed results are presented in Table 2, and Fig. S14.

Discussion

The current systematic review and meta-analysis of 250 studies comprising about half-million participants revealed that during the COVID-19 pandemic, the pooled estimated prevalence of sleep disturbances (including poor sleep quality and insomnia), independent of any covariate, was 40%. Bayesian meta-analysis revealed the same overall estimate of sleep disturbances, providing reassurance that this is likely a reasonable estimate of COVID-19 related sleep disturbance. Publication bias was minimal, and neither age nor gender moderated the overall pooled prevalence rate. A statistically significant variation was observed between countries, and overall results ranged from approximately 30% in China and India to 60% in Spain. Patients infected with COVID-19 appeared the most affected by sleep disturbances, with an overall pooled rate of 52%. Children and adolescents were the second most affected group, with an overall rate of sleep disturbances of approximately 46%. Healthcare workers, university students, and special populations had a similar magnitude of the problem, with an overall rate of approximately 41%. The general population appeared the least affected by the pandemic, with an overall prevalence of sleep disturbances of about 36%. Poor sleep quality appeared as the main problem and explained 52% of the variance in the data.

Meeting clinical diagnostic scores for insomnia was observed in 30%–40% of the overall participants; therefore, accounting for approximately 80% of the variance of total sleep disturbances. Sleep disturbances were more prevalent during lockdown periods than non-lockdown periods, 38% and 43%, respectively. The difference according to lockdown status did not reach statistical significance. Finally, a statistically significant increase was observed in studies published in 2021 compared to studies published in 2020, 36% and 47%, respectively.

Our global finding on the pooled prevalence rate of sleep disturbances during COVID-19 (40%) is consistent with two previous meta-analyses [2,10]. In the review, meta-regression revealed that age and sex had no bearing on the estimated prevalence of sleep disturbances. This finding was also reported in previous reviews [2,3,10].

Statistically significant differences were observed between countries, implying that the emergence of COVID-19, the local community transmission rate of the disease, measures taken to control the virus, and the pattern of media use [293] contributed to the magnitude of sleep disturbances. Recent data from COVIDiSTRESS Global Survey showed that stress and stress-related symptoms are positively associated with living in a nation or region where COVID-19 is more severe [294]. Additionally, cross-country discrepancies in public perception of stress have been reported [295]. The overlapping prevalence between psychological distress symptoms [296] and our findings on sleep disturbances suggests that there is a two-way relationship between sleep disturbances and psychiatric comorbidities, which indicates sleep experts should consider treating comorbidities in sleep disturbances and vice versa.

COVID19 patients can be expected to have the highest frequency of sleep disturbances (about 52%) because of the core symptoms of the disease, including cough, fever, inflammation, and shortness of breath, all of which are related to sleep disturbances [2]. The increased risk of sleep disturbances in COVID19 patients is likely also the result of body pain and the side effects of used medications.

Before the pandemic, a meta-analysis documented that 25% of normally developing children had sleep disturbances [297]. Therefore, the high prevalence of sleep disturbances among children (46%) observed during the pandemic is alarming. The most significant negative effect of the lockdown (schools closures), according to several studies, was a delay in the start of sleep and wake-up time [7]. Increased anxiety, inability to do outdoor activities, remote learning, and lack of in-person social connections all led to more time spent using technology, especially during the pre-sleep period [298]. Limited exposure to sunshine and extended exposure to screen blue and bright light from phones and computer screens (for school or play) may lead to disturbed circadian rhythms [299].

Previous reviews concluded that healthcare workers are among the populations most affected by sleep disturbances during the pandemic [2,4,5,10]. In addition, recent data demonstrated that during the pandemic, healthcare workers have a high prevalence of perceived stress, anxiety, and depression [53,300]. The present review documented that healthcare workers, university students, and special populations had a similar magnitude of sleep disturbances, with an overall rate of approximately 41%.

A key component in understanding sleep disturbances during the pandemic was shown to be lockdown. Current evidence suggests that social isolation and loneliness can harm mental health [301], and affect sleep quality [302,303].

Another interesting finding is that the reported prevalence of sleep disturbances in publications in 2021 appeared to be higher than in 2020, suggesting that the COVID-19 pandemic is continuing to have a negative impact on sleep. Since 2020, multiple epidemic waves with increasing infected cases [304], and the identification, spread, and impact of new COVID variants have led to “pandemic fatigue” [305]. Despite the availability of COVID-19 vaccines at the end of 2020, new waves could not be avoided across the globe, and the expected return to normal life now appears to be delayed or even uncertain. Moreover, several populations have experienced successive lockdowns since, which the current meta-analysis demonstrates is one of the major factors associated with COVID-19-related sleep disturbances. Hence, as the pandemic persists, more people are likely to develop sleep disturbances [193]. Findings that emerged from longitudinal follow-up studies revealed a significant worsening of sleep parameters over observational waves [306].

The findings of this review have several practical and research implications. First, screening programs and countermeasures for sleep disturbances must be developed and executed to help various groups detect and overcome sleep-related impairment. Specific programs need to be tailored for different populations, e.g., healthcare workers, children and adolescents, university students, and special populations, such as pregnant women, etc. Evidence-based strategies, e.g., cognitive behavioral therapy for insomnia [307], meditation [308], sports interventions [309], and wellness interventions [310], can be included in self-help applications, and healthcare staff can be trained to detect and treat sleep issues in various populations [311]. Second, special attention needs to be paid to insomnia as a formal disorder accounting for approximately 80% of the variance of sleep disturbances. Future primary and secondary research need to identify the magnitude of insomnia by severity; longitudinal studies are required to determine if insomnia is short-term or long-term. Third, our review showed that data saturation is achieved in certain populations, e.g., healthcare workers and the general populations; therefore, at least some research focus needs to be shifted to novel populations, e.g., post-COVID-19 populations, homeless individuals, those rough sleeping, and others. Fourthly, formal sleep assessment needs to be part of the comprehensive psychiatric evaluation for individuals seeking psychiatric services. Empirical results of a recent review documented the strong association between psychological distress and sleep disturbances [10], implying that both issues are best assessed and treated simultaneously.

The current review has several strengths. First, the rate of sleep disturbances has been assessed across several new populations that never received attention in previous reviews, e.g., special populations, university students, and children and adolescents. Second, robust statistical tests were used to handle bias, detect outliers, and examine heterogeneity. Third, because the pooled sample size was very large and the participants were recruited from many countries, the generalizability of the current review's conclusions is likely to be strong.

There are a few drawbacks to this review. First, the magnitude of heterogeneity in this meta-analysis was large. This is to be expected in a large epidemiological meta-analysis. The use of random-effects modeling was anticipated to deal with issues related to the effects of evaluating many studies that do not all follow the same pattern, but instead follow a distribution. Future reviews need finetuned aggregate data, and individual patient data (IPD) meta-analyses are desirable and should be encouraged to work out, analyze and present different aspects of sleep disturbances. Second, we included only limited moderators. When correcting for moderators, future reviews should expand this exploration using other lifestyle variables, including physical activity, smoking, and substance use, focusing on adjusting for stress-related illnesses such as post-traumatic stress disorder, adjustment disorders, anxiety, and depression. Besides sleep disturbances, there are many types of wakefulness disturbances that all have to do with staying awake at a time that is desirable or socially appropriate. These were beyond the scope of our analyses and discussion. Further reviewers are encouraged to address this under-investigated topic.

Conclusion

During the COVID-19 pandemic, sleep disturbances are common. Four in every ten individuals reported a sleep problem, and the main complaint is insomnia. Patients infected with COVID-19 and children and adolescents appeared to be the most affected groups. Healthcare workers, special populations, and university students had a similar but somewhat lower rate of sleep disturbances, while the general population appears to be the least affected. Lockdown is associated with a larger magnitude of sleep disturbances. More research is needed, particularly longitudinal studies, to establish the courses of sleep disturbances over time in these and populations, and such studies should pay particular attention to moderators, which may exacerbate sleep problem prevalence.

Practice points

- Sleep disturbances are common during the COVID-19 pandemic. The most affected groups were patients infected with the disease, children and adolescents, and university students. It is essential to develop and implement screening programs and countermeasures to help various groups detect and overcome sleep disturbances.
- There is a need to pay special attention to insomnia as a formal sleep disorder that accounts for 80% of sleep loss.
- During the pandemic, individuals seeking psychiatric treatment need a formal sleep assessment as part of their comprehensive evaluation.

Research agenda

- It is necessary to conduct future primary and secondary research to identify the severity of insomnia; longitudinal studies are needed to determine if insomnia is short-term or long-term.
- Meta-analyses of individual patient data (IPD) should be encouraged in future reviews and fine-tuned aggregate parameters should be included.
- The process of adjusting for moderators should expand the analysis by adding physical activity, smoking, and substance use, focusing on the prevalence of stress-related disorders.

Author agreement

All authors were involved in writing the paper and have seen and approved the manuscript.

Ethical statement

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

For this type of study (meta-analysis) formal consent is not required.

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Conflicts of interest

The authors do not have any conflicts of interest to disclose.

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Appendix A. Supplementary data

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