Sleep Medicine 100 (2022) 89–102

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Subjective sleep alterations in healthy subjects worldwide during COVID-19 pandemic: A systematic review, meta-analysis and meta-regression

Serena Scarpelli [a, 1], Andrea Zagaria [a, 1], Pietro-Luca Ratti [b], Antonio Albano [c], Vincenzo Fazio [c], Alessandro Musetti [d], Giorgia Varallo [c], Gianluca Castelnuovo [e, f], Giuseppe Plazzi [g, h], Christian Franceschini [c, *]

[a] Department of Psychology, Faculty of Medicine and Psychology, Sapienza University of Rome, Italy
[b] Neurocenter of Southern Switzerland, Regional Hospital of Lugano, Lugano, Switzerland and Al Centro del Sonno, Venice, Italy
[c] Department of Medicine and Surgery, Faculty of Medicine and Surgery, University of Parma, Italy
[d] Department of Humanities, Social Sciences and Cultural Industries, University of Parma, Parma, Italy
[e] Department of Psychology, Catholic University of Milan, Milan, Italy
[f] Psychology Research Laboratory, Istituto Auxologico Italiano IRCCS, Milan, Italy
[g] Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Modena, Italy
[h] IRCCS Istituto Delle Scienze Neurologiche di Bologna, Bologna, Italy

ARTICLE INFO

Article history:
Received 2 May 2022
Received in revised form
4 July 2022
Accepted 18 July 2022
Available online 10 August 2022

Keywords:
COVID-19
SARS-CoV-2
Sleep
Sleep quality
Subjective sleep
Sleep alterations
Pittsburgh sleep quality index
Insomnia
Government stringency index

ABSTRACT

Objective: We conducted a systematic review and meta-analysis to provide an update on sleep quality in different world areas and better characterize subjective sleep alterations during the COVID-19 pandemic. Considering gender distribution and specific pandemic-related parameters, we also intend to identify significant predictors of sleep problems.

Methods: Six electronic databases were searched from December 2019 to November 2021 for studies investigating sleep during COVID-19 employing the Pittsburgh Sleep Quality Index, the Medical Outcomes Study Sleep, the Insomnia Severity Index or the Epworth Sleepiness Scale. Random-effects models were implemented to estimate the pooled raw means of subjective sleep alterations. Also, we considered the role of several pandemic-related parameters (i.e., days from the first COVID-19 case, government stringency index, new cases for a million people, new deaths for a million people) by means of meta-regression analyses.

Results: A total of 139 studies were selected. The pooled mean of the global Pittsburgh Sleep Quality Index score ($PSQI_{gen}$) was 6.73 (95% CI, 6.61–6.85). The insomnia severity index score was reported from 50 studies with a pooled mean of 8.44 (95% CI, 7.53–9.26). Subgroup analyses confirmed that most subcategories had poor sleep quality and subclinical insomnia. Meta-regressions showed that $PSQI_{gen}$ was predicted by days from the first COVID-19 case and government restrictions with a negative slope and by female gender with a positive slope. The government stringency index was positively correlated with the direct subjective evaluation of sleep quality.

Conclusions: We found an overall impaired sleep and widespread subthreshold insomnia during the COVID-19 pandemic. The female percentage seems to be the best predictor of impaired sleep quality, consistently to the available literature. Noteworthy, sleep alterations were inversely associated with governmental restrictions and decreased during the pandemic. Our results give a contribution to critically orienting further studies on sleep since COVID-19 pandemic.

1. Introduction

The pandemic caused by the Coronavirus disease (COVID-19) has been considered a significant stressful life event associated

* Corresponding author. Department of Medicine and Surgery, University of Parma, Via Volturno 39, 43126, Parma, Italy.
E-mail address: christian.franceschini@unipr.it (C. Franceschini).

[1] Serena Scarpelli and Andrea Zagaria contributed equally to the manuscript.

https://doi.org/10.1016/j.sleep.2022.07.012
1389-9457/

with increased psychological problems, including poor sleep quality [1,2]. Several studies [2–6] published between December 2019 and November 2021 carried out in different countries worldwide investigated sleep problems during the COVID-19 pandemic by self-report questionnaires and confirmed a trend towards sleep disruption.

Recently, meta-analyses on sleep disturbances during the pandemic have been published [7–14]. Three studies reported a global prevalence of sleep disturbance during the COVID-19 pandemic of approximately 30–40% [7,8,10], with the highest rate of sleep disturbance in patients with COVID-19 infection (52–75%) [7,8,10]. Notably, two of these meta-analyses included investigations using both validated instruments and researcher-developed items designed to measure sleep alterations [7,8]. Most of the meta-analyses focused on healthcare workers [11,12,14,15] and reported a rate of sleep disturbances – assessed by the Pittsburgh Sleep Quality Index (PSQI; [16]), the Insomnia Severity Index (ISI; [17]) and the Athens Insomnia Scale (AIS; [18]) - around 35% in this population [12,15], with a prevalence greater than 40% among health professionals [11,14]. Moreover, to the best of our knowledge, previous meta-analyses did not investigate either specific sleep symptoms or the relationship between these alterations and pandemic-related parameters referred to the time interval the data were collected in.

The aim of this meta-analysis is threefold. First, to provide an update about sleep quality data in different populations during COVID-19 pandemic, and in different world areas. Second, to provide a better characterization of the subjective sleep alterations according to standardized self-report parameters of sleep quality. Third, to establish a quantitative relationship between specific sleep alterations and pandemic-related measures. In particular, we aim to assess the best predictors of sleep alterations through meta-regressions, considering the gender distribution in the surveys, the time between the research and the announcement of the first COVID-19 case, the government stringency index (GSI), new cases for a million people, and new deaths for a million people.

2. Materials and methods

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [19] and was registered to the PROSPERO international database of the University of York Centre for Reviews (https://www.crd.york.ac.uk/prospero/) (ID: CRD42021298474) to guarantee transparency and quality standards of the review.

2.1. Search strategy

One author (AA) performed a systematic literature search using five electronic databases (PubMed, MEDLINE, ScienceDirect, Scopus, Web of Science) from December 1, 2019, to November 30, 2021. We searched for title and abstract using the following string: (COVID-19 OR coronavirus OR 2019-nCoV OR SARS-CoV-2) AND (sleep disorders OR sleep problems OR sleep quality OR sleep difficulties) AND (Pittsburgh Sleep Quality Index OR Medical Outcomes Study Sleep OR Insomnia Severity Index OR Epworth Sleepiness Scale). Additionally, we expanded our search through other sources (i.e., backward, and forward citation tracking of all included articles). Once duplicates were removed, to establish which papers met eligibility criteria two authors (AA and VF) independently screened titles, abstracts, tables, and graphs in the first screening step, and full texts in the second eligibility step. Disagreements between the two judges were resolved by consensus.

2.2. Inclusion and exclusion criteria

According to the Population, Intervention, Comparison, Outcome, Study design (PICOS) approach, the inclusion criteria were: 1) Population: general population of any age and gender, without major sleep disorder, medical and psychiatric comorbidity; 2) Intervention: exposure to COVID-19 pandemic (i.e., studies conducted from December 2019); 3) Comparison: not available; 4) Outcomes: subjective standardized measures of sleep quality (i.e., PSQI [16], Medical Outcomes Study Sleep - MOS-S [20], ISI [17], Epworth Sleepiness Scale - ESS [21]) 5) Study design: no limits of study design were imposed.

The exclusion criteria were: 1) data collected outside the timeline of COVID-19 pandemic; 2) data not including subjective sleep assessment using PSQI or MOS-S or ISI or ESS; 3) sample with sleep or psychiatric disorders or pathological health conditions; 4) sample with COVID-19 patients; 5) sample with pregnant women; 6) participants undergoing interventions or therapies to improve sleep quality; 7) review or meta-analysis papers (2% of screened papers); 8) gray literature (1% of screened papers); 9) papers that were not written in English; 10) papers that did not report data needed for meta-analytic calculations (i.e., mean values).

2.3. Outcome

The studies assessing sleep alterations by means of the PSQI [16], the MOS-S [20], the ISI [17], and the ESS scales [21] were considered in this meta-analysis. The PSQI is a self-report questionnaire which provides an estimate of global sleep quality relative to the previous 30 days. The global score ($PSQI_{gen}$) ranges from 0 to 21, with a cutoff >5 indicating “poor sleepers”. Besides the global score, different sleep features are defined by specific subcomponents: $PSQI_{c1}$ = Subjective sleep quality; $PSQI_{c2}$ = Sleep latency; $PSQI_{c3}$ = Sleep duration; $PSQI_{c4}$ = Habitual sleep efficiency; $PSQI_{c5}$ = Sleep disturbances; $PSQI_{c6}$ = Sleeping medication use; $PSQI_{c7}$ = Daytime dysfunction [16]. The ISI is a self-questionnaire to estimate the nature, severity, and impact of insomnia on a scale from 0 to 28. Score ranges can be interpreted as: 0–7 = “no insomnia”, 8–14 = “mild insomnia”, 15–21 = “moderate insomnia, and 22–28 = “severe insomnia” [17]. Also, the MOS-S is a self-report questionnaire providing an estimate of sleep disturbance. The MOS-S is divided in six subscales: sleep disturbance, snoring, respiratory/shortness of breath, sleep quantity, adequacy of sleep, and daytime somnolence [20]. Lastly, the ESS is a self- report questionnaire that assesses daytime sleepiness on a scale from 0 to 24. Scores of 10 and above indicate “excessive daytime sleepiness” [21].

The included studies were categorized according to the following populations: children (age range: from 2 to 5 years), adolescents (age range: from 11 to 19 years), general population, healthcare workers and students (university students). Also, the studies were classified according to the present world regions: Africa, America, Asia, Europe, International, Middle East, Oceania.

Moreover, the following COVID-19 pandemic-related measures were hypothesized to predict sleep alterations: GSI, new cases for a million people, and new deaths for a million people. The GSI is a measure calculated by the Oxford Coronavirus Government Response Tracker. This index is compounded from the following metrics: school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls [22]. From this web link is possible to see how the index was calculated.

2.4. Data extraction

One author (AA) recorded the information from the included studies using a pre-defined datasheet form. A second author (VF) cross-checked this step. We extracted the following study characteristics: 1) sample sizes; 2) measures used to assess sleep quality; 3) study location; 4) percentage of female participants; 5) age (mean, median, or interval); 6) type of population (e.g., students, health workers); 7) period in which the study was conducted; 8) data for meta-analytic calculations. From the web link ourworldindata.org, we also extracted the following data: GSI, new cases for a million people, new deaths for a million people. These data were gathered for each country considering the timeline in which the research was done.

2.5. Quality appraisal

We used the Newcastle–Ottawa Scale (NOS) [23] for cross-sectional studies to assess the risk of bias of included papers. The NOS consists of three domains: selection (e.g., sample size), comparability (e.g., the subjects in different outcome groups are comparable, based on the study design or analysis), and exposure or outcome (e.g., ascertainment of exposure, assessment of the outcome). A study can be awarded a maximum of one star for each item within the selection and outcome domains. A maximum of two stars can be given for the comparability domain. The total scores range from 0 to 10, with higher score indicating higher study quality. The studies with scores <5 were considered papers with a high risk of bias [24]. Two authors (AA and VF) independently assessed the risk of bias and disagreements between the two judges were resolved by discussion.

2.6. Data analysis

The analysis was performed with R, version 4.1.2, using meta [25] and dmetar [26] packages. Random-effects models were implemented to estimate the pooled raw means of subjective sleep alterations during COVID-19. More specifically, we calculated the pooled means using the inverse variance method with DerSimonian-Laird estimator [27] to calculate the heterogeneity variance τ^2 and Jackson method [28] for confidence intervals of τ^2 and τ, while the Hartung-Knapp adjustment [29,30] was applied to address uncertainty in estimate of the between-study variance. Publication bias was assessed by the visual inspection of the funnel plots [31], Begg & Mazumdar's rank correlation test [32] and Egger's test for funnel plot asymmetry [31]. If the publication bias was statistically significant, the trim-and-fill method [33] to adjust for funnel plot asymmetry was applied. We tested between-study heterogeneity with Cochran's Q [34] and I^2 statistic [35], where I^2 values of 25%, 50% and 75% reflect low, moderate, and high amount of heterogeneity, respectively. Afterward, subgroup analyses under random-effects models were conducted to identify possible sources of heterogeneity according to the following categorical variables: study location (i.e., America, Asia, Europe, Middle East, Oceania), type of population (i.e., adolescents, children, general, health workers, students), gender (i.e., only males; only females; both) and risk of bias (i.e., high, low). Q-tests were used to evaluate whether subgroup differences are large enough not to be explained by sampling error alone [36]. We also hypothesized that the raw means may be predicted by the following continuous variables: female percentage, days (i.e., number of days between the central day of the research and December 31, 2019), GSI, new cases for a million people, and new deaths for a million people. Therefore, we carried out six meta-regressions under random-effects models for each global scale and single component. Lastly, multimodel inference (i.e., 64 fitted models) was employed to evaluate the averaged importance of each predictor in explaining differences in pooled raw means [36] (see Supplementary Document 1).

3. Results

3.1. Study selection

A total of 1084 records were identified through database searching and other sources (PubMed = 271, MEDLINE = 251, ScienceDirect = 63, Scopus = 257, Web of Science = 218, Other sources = 24). After removing duplicates, 456 records were retained and screened based on the title, abstract, tables and graphs. A total of 139 potential papers were full-text screened, and no additional studies were excluded during the second eligibility step. Hence, a total of 139 articles [37–175] were included in the systematic review and meta-analysis. The PRISMA flow diagram (Fig. 1) summarizes the entire process.

3.2. Study characteristics

A detailed description of the included studies is reported in Table 1. One hundred-thirty-nine papers were included in our systematic review involving participants from 30 countries. The median number of participants was 338. Excluding manuscripts that reported age as range or median (i.e., 28%) [41,44–46,48,59,61–63,69,73,75], [84,87,96,98–101,104,111,112,121], [126,134,137,141,144,145,147], [158,161,163–165,167,169,175], the mean age of the participants was 32.22 ± 9.35 years. Regarding the administered sleep measures, 103 studies reported PSQI scores. Specifically, 100 reported PSQI global scores [37–40,42,43,45], [46,48–53], [55–63,65–68], [70–73,75,77–84,86,87], [91–94,96–98,102,103,106–110], [113–116,119,120,122–125], [127–132,134–141], [143–146,149–151,153–156], [158,159,164,165,168,169,171–173], 43 reported both PSQI global score and subscale scores [37–39,41,43,45,46,49], [53,61,65,66,70,71,73,80,82], [83,87,91,94,97,102,107–109], [114,119,124,134,140,141,143–145], [148,149,153,154,160,164,169,171] and 3 studies only PSQI subscale scores [41,148,160]. Further, 41 studies reported ISI scores [44,47,50,54,64,69,74], [76,85,88–90,95], [99–101,104,105,110–112], [117,118,121,126,128,129], [133,139,142,147,152,157], [161–163,166,167,170,174,175]. No study reported the mean score of the MOS-S, while only two studies [67,129] reported the mean score of the ESS. For this reason, we were not able to perform meta-analytic analyses on MOS-S and ESS scores.

The type of population was categorized as follow: adolescents (6 studies) [71,81,87,92,108,138], children (1 study) [38], general population (66 studies) [40,42,43,46,48,49], [51–57,59,60,64–66], [68–70,72,73,76,78–80], [82–85,88,89,101,103], [104,109,110,113,117,120,121], [123,128,129,131,134,135,137], [139,141–145,147,150–152], [154,155,157,159,161,163,167], health workers (53 studies) [37,39,41,44,45,47,50,58], [61–63,67,74,77,90,91,93–99], [102,105,107,111,112,115,118,119], [122,126,127,130,132,146,148,149], [153,156,158,160,162], [164–166,168,169,171–174], students (13 studies) [75,86,100,106,114,116,124], [125,133,136,140,170,175].

3.3. Study quality

The Newcastle-Ottawa Scale (NOS) for cross-sectional studies was used to assess the methodological quality of included papers, obtaining homogeneous results. The total scores ranged from 3 to 6. Most of the studies (114) [37–46], [48–60], [63–68], [70–73,75–77], [79–89,91,93–99], [101–110,113–117], [119–126,128–131], [133–137,139,141–147], [149–159,161], [163–165,167,169,171,173] got a low risk of bias (see Table 1). In most of the

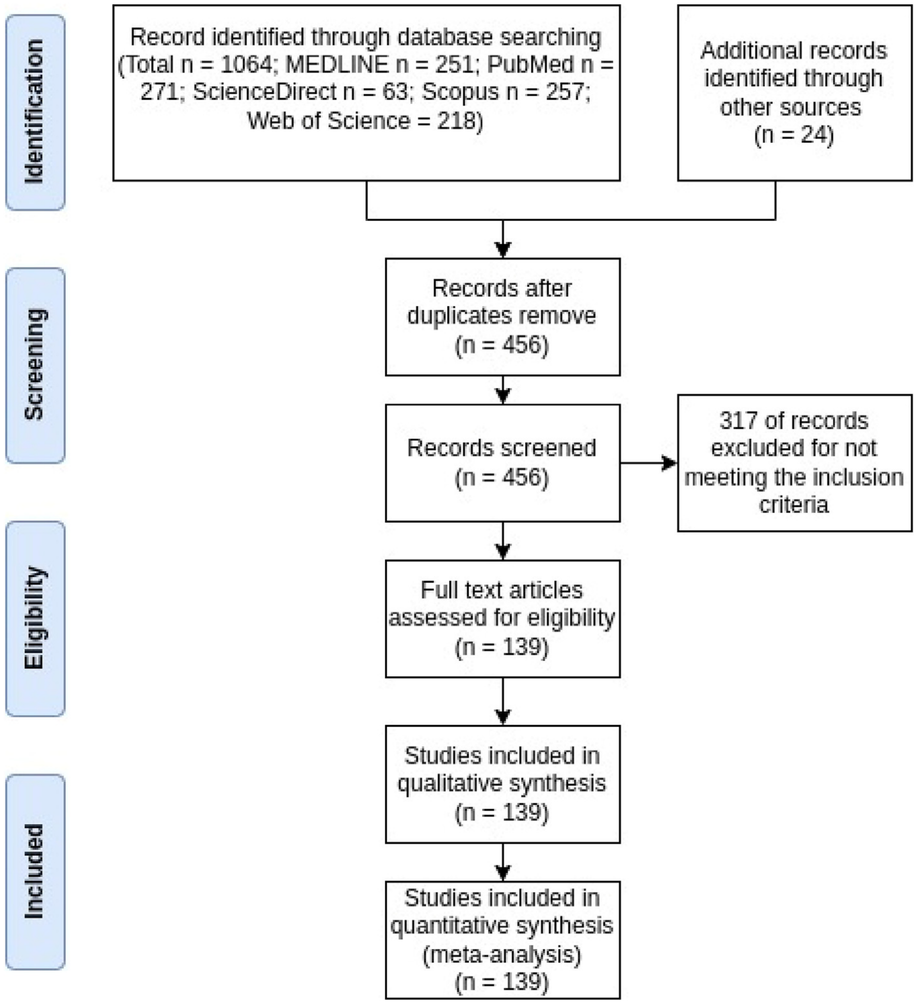

Fig. 1. PRIMA search flow.

included studies the sample size was justified and satisfactory, also ensuring the assessment of sleep quality in a valid and reliable way. We established that there was no comparability between respondents' and non-respondents' characteristics, therefore we assigned always zero to this item. Lastly, the assessment of the outcome was done by self-reported questionnaires, consequently we assigned one point to this domain.

3.4. Meta-analysis

The $PSQI_{gen}$ was reported in 100 studies, from which we were able to derive 115 records ($k = 115$, $n = 81{,}320$). The $PSQI_{gen}$ pooled mean was 6.73 (95% CI, 6.61–6.85) with a significant and high heterogeneity ($Q = 220{,}984$, $df = 114$, $p<0.001$; $I^2 = 99.9\%$). Both Egger's and Begg and Mazumdar's tests did not indicate possible publication bias ($ps > 0.05$). Next, ISI score was reported from 50 included studies showing a pooled mean of 8.44 (95% CI, 7.53–9.26) with a still pronounced heterogeneity ($Q = 220{,}984$, $df = 49$, $p<0.001$; $I^2 = 100\%$). Formal tests did not indicate funnel plot asymmetry (both $ps > 0.05$) We also calculated the pooled means for all sub-components of PSQI. More details on these analyses are reported in Table 2. Note that in case of statistically significant publication bias (i.e., $PSQI_{c1}$, $PSQI_{c3}$, $PSQI_{c4}$, $PSQI_{c6}$, $PSQI_{c7}$), the trim-and-fill procedure was applied to adjust for funnel plot asymmetry.

3.5. Subgroup analyses

A series of subgroup analyses were conducted to explore potential sources of heterogeneity addressing the roles of study location, type of population, gender, and risk of bias. Although heterogeneity remained still pronounced in all analyses (see Supplementary Document 1), several tests of subgroup differences were meaningful as shown in Table 3. First, we found significant subgroup effects of study location on $PSQI_{gen}$ ($p < 0.001$), $PSQI_{c1}$ ($p = 0.004$), $PSQI_{c2}$ ($p < 0.001$), $PSQI_{c5}$ ($p = 0.004$), $PSQI_{c7}$ ($p<0.001$), and ISI ($p < 0.001$) scores. Then, subgroup effects of type of population were significant on $PSQI_{c1}$ ($p = 0.02$), $PSQI_{c2}$ ($p = 0.01$), $PSQI_{c3}$ ($p < 0.001$), $PSQI_{c7}$ ($p < 0.001$) scores. Lastly, subgroup effects of risk of bias were statistically significant on $PSQI_{gen}$ ($p = 0.003$) and $PSQI_{c7}$ ($p = 0.01$) scores. More details on these analyses, such as the pooled raw means calculated for each subgroup, were reported in Supplementary Document 1. Findings from subgroup analyses highlighted that most of the subcategories with respect to geographic distribution, gender, population, and risk of bias reported poor sleep quality (i.e., $PSQI_{gen} > 5$) and subthreshold insomnia (i.e., ISI >7).

3.6. Meta-regression analyses

As a further step, we verified whether the meta-analytic

Table 1
Study characteristics.

Author	Country	Sample (n)	Female	Age	Type of pop.	Measure	NOS
Abbas et al., 2021 [37]	Kuwait	217	0.44	x = 35.8y	health w.	$PSQI_{gen-sub}$	5
Abid et al., 2021 (a) [38]	Tunisia	48	1	x = 8.66y	children	$PSQI_{gen}$	5
Abid et al., 2021 (b) [38]	Tunisia	52	0	x = 8.66y	children	$PSQI_{gen}$	5
Akıncı and Başar, 2021 [39]	Turkey	152	0.63	x = 35.8y	health w.	$PSQI_{gen-sub}$	5
Akkuş et al., 2021 [40]	Turkey	595	0.66	x = 27.9y	general	$PSQI_{gen}$	6
Al Maqbali, 2021 [41]	Oman	987	0.91	>18y	health w.	$PSQI_{sub}$	5
Al-Musharaf et al., 2021 [42]	Saudi Arabia	297	1	x = 20.7y	general	$PSQI_{gen}$	5
Alfonsi et al., 2021 (a) [43]	Italy	72	1	x = 35.68y	general	$PSQI_{gen-sub}$	6
Alfonsi et al., 2021 (b) [43]	Italy	28	0	x = 35.68y	general	$PSQI_{gen-sub}$	6
AlGhufli et al., 2021 (a) [44]	UAE	338	1	18y to 60y	health w.	ISI	5
AlGhufli et al., 2021 (b) [44]	UAE	62	0	18y to 60y	health w.	ISI	5
Alharbi et al., 2021 (1) [45]	Saudi Arabia	238	0.84	30 to > 40y	health w.	$PSQI_{gen-sub}$	6
Alharbi et al., 2021 (2a) [46]	Saudi Arabia	419	1	>18y	general	$PSQI_{gen-sub}$	6
Alharbi et al., 2021 (2b) [46]	Saudi Arabia	371	0	>18y	general	$PSQI_{gen-sub}$	6
Ali et al., 2021 [47]	Bangladesh	294	0.43	x = 28.86y	health w.	ISI	4
Alqahtani et al., 2021 (a) [48]	Saudi Arabia	251	1	20y to > 50y	general	$PSQI_{gen}$	6
Alqahtani et al., 2021 (b) [48]	Saudi Arabia	342	0	20y to > 50y	general	$PSQI_{gen}$	6
AlRasheed et al., 2021 [49]	Saudi Arabia	353	0.63	x = 27.8y	general	$PSQI_{gen-sub}$	6
Amra et al., 2021 [50]	Iran	337	0.65	x = 34.5y	health w.	$PSQI_{gen}$/ISI	5
Assenza et al., 2020 [51]	Italy	472	0.8	x = 42.3y	general	$PSQI_{gen}$	5
Banthiya et al., 2021 [52]	India	808	0.57	x = 30.85y	general	$PSQI_{gen}$	6
Barrea et al., 2020 [53]	Italy	121	0.64	x = 44.9y	general	$PSQI_{gen-sub}$	6
Bartoszek et al., 2020 [54]	Poland	471	0.86	x = 25.5y	general	ISI	6
Başkan and Güneş, 2021 [55]	Turkey	1909	0.69	x = 31.93y	general	$PSQI_{gen}$	6
Bazzani et al., 2021 (a) [56]	Italy	803	1	x = 39.17y	general	$PSQI_{gen}$	6
Bazzani et al., 2021 (b) [56]	Italy	495	0	x = 39.17y	general	$PSQI_{gen}$	6
Bhat et al., 2020 [57]	International	264	0.28	x = 31.45y	general	$PSQI_{gen}$	6
Bilgiç et al., 2021 [58]	Turkey	316	0.85	x = 32.24y	health w.	$PSQI_{gen}$	5
Bücker et al., 2021 [59]	Brazil	327	0.74	18y to 72y	general	$PSQI_{gen}$	5
Cellini et al., 2020 (a) [60]	Italy	501	0.63	x = 26y	general	$PSQI_{gen}$	6
Cellini et al., 2020 (b) [60]	Italy	809	0.70	x = 22.6y	students	$PSQI_{gen}$	5
Chen et al., 2021 (1) [61]	China	597	0.88	18y to > 46y	health w.	$PSQI_{gen-sub}$	4
Chen et al., 2021 (2) [62]	China	20	0.55	me = 35y	health w.	$PSQI_{gen}$	3
Cheng et al., 2020 [63]	China	534	0.82	20 to > 50y	health w.	$PSQI_{gen}$	5
Cheng et al., 2021 [64]	USA	196	0.78	x = 44.7y	general	ISI	6
Conte et al., 2021 (1) [65]	Italy	82	0.49	x = 34.5y	general	$PSQI_{gen-sub}$	6
Conte et al., 2021 (2) [66]	Italy	214	0.74	x = 36.79y	general	$PSQI_{gen-sub}$	6
Costa et al., 2021 [67]	Italy	119	0.53	x = 30.66y	health w.	$PSQI_{gen}$	5
Czenczek-Lewandowska et al., 2021 [68]	Poland	506	0.70	x = 24.67y	general	$PSQI_{gen}$	5
Dale et al., 2021 (a) [69]	Austria	764	1	>18y	general	ISI	4
Dale et al., 2021 (b) [69]	Austria	741	0	>18y	general	ISI	4
Demartini et al., 2020 (a) [70]	Italy	309	0.69	x = 35.9y	general	$PSQI_{gen-sub}$	6
Demartini et al., 2020 (b) [70]	Italy	123	0.79	x = 35.9y	health w.	$PSQI_{gen-sub}$	5
Ding and Yao, 2020 [71]	China	71	0.45	x = 15.3y	adolescents	$PSQI_{gen-sub}$	5
Du et al., 2021 [72]	International	2196	0.67	x = 22.5y	general	$PSQI_{gen}$	5
Duran and Erkin, 2021 [73]	Turkey	405	0.71	>18y	general	$PSQI_{gen-sub}$	6
Engin et al., 2021 [74]	Turkey	360	0.49	x = 38.6y	health w.	ISI	4
Eleftheriou et al., 2021 [75]	Greece	559	0.7	>18y	students	$PSQI_{gen}$	5
Elhadi et al., 2021 [76]	Libya	10,296	0.78	x = 28.9y	general	ISI	5
Fidanci et al., 2020 [77]	Turkey	153	0.67	x = 33.4y	health w.	$PSQI_{gen}$	5
Forte et al., 2020 [78]	Italy	2286	0.75	x = 29.61y	general	$PSQI_{gen}$	4
Gao and Scullin, 2020 [79]	USA	86	0.45	x = 38.23y	general	$PSQI_{gen}$	5
Gargiulo et al., 2021 [80]	USA	393	0.51	x = 45.08y	general	$PSQI_{gen-sub}$	5
Genta et al., 2021 [81]	Brazil	94	0.64	x = 16.4y	adolescents	$PSQI_{gen}$	5
Gorgoni et al., 2021 (1) [82]	Italy	102	0.83	x = 36.69y	general	$PSQI_{gen-sub}$	5
Gorgoni et al., 2021 (2) [83]	Italy	1091	0.72	x = 31.3y	general	$PSQI_{gen-sub}$	5
Gu et al., 2021 [84]	China	289	0.72	<18y to 60y	general	$PSQI_{gen}$	6
Hao et al., 2020 [85]	China	109	0.62	x = 33.1y	general	ISI	5
Harriger et al., 2021 [86]	USA	490	0.74	x = 20.4y	students	$PSQI_{gen}$	5
Helito et al., 2021 [87]	Brazil	82	0.58	me = 15y	adolescents	$PSQI_{gen-sub}$	5
Huang et al., 2020 [88]	China	1172	0.69	x = 28.39y	general	ISI	6
Huang et al., 2021 (1a) [89]	China	1091	0.69	x = 31.2y	general	ISI	6
Huang et al., 2021 (1b) [89]	China	605	0.81	x = 32.8y	health w.	ISI	5
Huang et al., 2021 (2) [90]	China	507	0.83	x = 37.53y	health w.	ISI	4
Jahrami et al., 2020 [91]	Bahrain	257	0.70	x = 40.20y	health w.	$PSQI_{gen-sub}$	5
Jamieson et al., 2021 [92]	Australia	30	0.43	x = 14.02y	adolescents	$PSQI_{gen-sub}$	4
Jiang et al., 2021 [93]	China	569	0.60	x = 34y	health w.	$PSQI_{gen}$	5
Jin et al., 2021 (a) [94]	China	222	1	x = 25.1y	health w.	$PSQI_{gen-sub}$	5
Jin et al., 2021 (b) [94]	China	182	0	x = 25.1y	health w.	$PSQI_{gen-sub}$	5
Kandemir et al., 2021 [95]	Turkey	194	0.71	x = 29.99y	health w.	ISI	5
Khan et al., 2021 (a) [96]	Pakistan	810	0.57	>18y	health w.	$PSQI_{gen}$	5
Khan et al., 2021 (b) [96]	India	812	0.57	>18y	health w.	$PSQI_{gen}$	5
Khan et al., 2021 (c) [96]	Nepal	168	0.45	>18y	health w.	$PSQI_{gen}$	5

(continued on next page)

Table 1 (*continued*)

Author	Country	Sample (n)	Female	Age	Type of pop.	Measure	NOS
Kim-Godwin et al., 2021 [97]	USA	215	1	x = 36.07y	health w.	PSQI$_{gen\text{-}sub}$	5
Korkmaz et al., 2020 [98]	Turkey	140	0.44	18y to 65y	health w.	PSQI$_{gen}$	5
Krupa et al., 2021 (a) [99]	Poland	298	1	>20y	health w.	ISI	5
Krupa et al., 2021 (b) [99]	Poland	38	0	>20y	health w.	ISI	5
Lai et al., 2020 (a) [100]	China	38	1	>18y	students	ISI	4
Lai et al., 2020 (b) [100]	China	45	0	>18y	students	ISI	4
Lam et al., 2021 [101]	China	339	0.65	18 to > 60y	general	ISI	6
Lin et al., 2021 (1) [102]	China	384	0.73	x = 34.13y	health w.	PSQI$_{gen\text{-}sub}$	5
Lin et al., 2021 (2) [103]	China	1897	0.44	x = 36.6y	general	PSQI$_{gen}$	6
Lin et al., 2021 (3) [104]	China	4087	0.70	any	general	ISI	6
Liu et al., 2020 [105]	China	606	0.81	x = 35.7y	health w.	ISI	5
Liu et al., 2021 (1) [106]	China	1200	0.48	x = 23.36y	students	PSQI$_{gen}$	6
Liu et al., 2021 (2) [107]	China	140	0.94	x = 32.39y	health w.	PSQI$_{gen\text{-}sub}$	5
Luo et al., 2021 [108]	China	34	0.49	x = 13.96y	adolescents	PSQI$_{gen\text{-}sub}$	5
Maestro-Gonzalez et al., 2021 [109]	Spain	5220	0.74	x = 39.48y	general	PSQI$_{gen\text{-}sub}$	6
Marelli et al., 2021 [110]	Italy	400	0.76	x = 37.02y	general	PSQI$_{gen}$/ISI	6
Martín et al., 2021 (1) [111]	Spain	210	0.86	>18y	health w.	ISI	4
Martín et al., 2021 (2) [112]	Spain	2082	0.81	>18y	health w.	ISI	4
Martínez-de Quel et al., 2021 [113]	Spain	161	0.37	x = 35y	general	PSQI$_{gen}$	6
Martínez-de Quel et al., 2020 [114]	Spain	102	0.80	x = 21.67y	students	PSQI$_{gen\text{-}sub}$	5
Meo et al., 2021 [115]	Saudi Arabia	1678	0.51	x = 34.1y	health w.	PSQI$_{gen}$	5
Milasauskiene et al., 2021 [116]	Lithuania	524	0.79	x = 23.7y	students	PSQI$_{gen}$	5
Miranda and Scotta, 2021 [117]	Argentina	305	1	x = 30.51y	general	ISI	5
Mousavi et al., 2021 (a) [118]	Iran	236	1	x = 33.5y	health w.	ISI	4
Mousavi et al., 2021 (b) [118]	Iran	84	0	x = 33.5y	health w.	ISI	4
Olagunju et al., 2021 [119]	Canada	303	0.40	x = 38.8y	health w.	PSQI$_{gen\text{-}sub}$	5
Peng et al., 2020 [120]	China	2098	0.42	x = 36.89y	general	PSQI$_{gen}$	5
Pieh et al., 2021 [121]	Austria	437	0.53	>18y	general	ISI	5
Qi et al., 2020 [122]	China	1306	0.80	x = 33.1y	health w.	PSQI$_{gen}$	5
Robillard et al., 2021 [123]	Canada	4996	0.67	x = 54.6y	general	PSQI$_{gen}$	5
Romero-Blanco et al., 2020 [124]	Spain	207	0.82	x = 20.6y	students	PSQI$_{gen\text{-}sub}$	5
Saadeh et al., 2021 [125]	Jordan	6157	0.71	x = 19.79y	students	PSQI$_{gen}$	5
Sagherian et al., 2020 [126]	USA	564	0.94	any	health w.	ISI	5
Sahin et al., 2021 [127]	Turkey	169	0.44	x = 33.9y	health w.	PSQI$_{gen}$	4
Salfi et al., 2020 (a) [128]	Italy	2210	1	x = 32.37y	general	PSQI$_{gen}$/ISI	6
Salfi et al., 2020 (b) [128]	Italy	491	0	x = 32.37y	general	PSQI$_{gen}$/ISI	6
San Martin et al., 2020 (a) [129]	Spain	70	0.59	x = 37.9y	general	PSQI$_{gen}$/ISI	6
San Martin et al., 2020 (b) [129]	Spain	100	0.59	x = 35.3y	health w.	PSQI$_{gen}$/ISI	5
Santos et al., 2021 [130]	Brazil	45	0.62	x = 39.3y	health w.	PSQI$_{gen}$	5
Sañudo et al., 2020 [131]	Spain	20	0.47	x = 22.6y	general	PSQI$_{gen}$	5
Saracoglu et al., 2020 [132]	Turkey	208	0.28	x = 29y	health w.	PSQI$_{gen}$	4
Scotta et al., 2020 [133]	Argentina	584	0.81	x = 22.49y	students	ISI	5
Sella et al., 2021 (a) [134]	Italy	17	0.53	18y to 35y	general	PSQI$_{gen\text{-}sub}$	5
Sella et al., 2021 (b) [134]	Italy	21	0.52	65y to 90y	general	PSQI$_{gen\text{-}sub}$	5
Shillington et al., 2021 [135]	Canada	2192	0.9	x = 43y	general	PSQI$_{gen}$	6
Shrestha et al., 2021 [136]	Nepal	168	0.36	x = 21.57y	students	PSQI$_{gen}$	5
Şimşek et al., 2020 [137]	Turkey	757	/	15 to > 40y	general	PSQI$_{gen}$	6
Siste et al., 2021 [138]	Indonesia	2932	0.79	x = 17.38y	adolescents	PSQI$_{gen}$	4
Solon Júnior et al., 2021 [139]	Brazil	53	0.55	x = 23.12y	general	PSQI$_{gen}$/ISI	6
Soylu, 2021 [140]	Turkey	392	0.62	x = 22.9y	students	PSQI$_{gen\text{-}sub}$	4
Tahir et al., 2021 (a) [141]	International	1758	1	15y to 44y	general	PSQI$_{gen\text{-}sub}$	6
Tahir et al., 2021 (b) [141]	International	991	0	15y to 44y	general	PSQI$_{gen\text{-}sub}$	6
Tan et al., 2020 [142]	China	673	0.26	x = 30.8y	general	ISI	5
Targa et al., 2020 [143]	Spain	71	0.75	x = 40.7y	general	PSQI$_{gen\text{-}sub}$	6
Trabelsi et al., 2021 (1) [144]	International	517	0.52	56y to > 80y	general	PSQI$_{gen\text{-}sub}$	6
Trabelsi et al., 2021 (2) [145]	International	5056	0.59	18 to > 55y	general	PSQI$_{gen\text{-}sub}$	6
Tu et al., 2020 [146]	China	100	1	x = 34.44y	health w.	PSQI$_{gen}$	5
Verma et al., 2021 [147]	USA	591	0.49	25y to 85y	general	ISI	6
Wang et al., 2020 (1) [148]	China	106	0.64	x = 36.6y	health w.	PSQI$_{sub}$	4
Wang et al., 2020 (2) [149]	China	123	0.90	x = 33.75y	health w.	PSQI$_{gen\text{-}sub}$	5
Wang et al., 2020 (3) [150]	China	6437	0.56	x = 31.4y	general	PSQI$_{gen}$	5
Wilson et al., 2021 [151]	New Zeland	41	0.15	x = 44y	general	PSQI$_{gen}$	5
Wong et al., 2020 [152]	China	583	0.73	x = 70.85y	general	ISI	5
Wu and Wei, 2020 [153]	China	60	0.75	x = 33.8y	health w.	PSQI$_{gen\text{-}sub}$	5
Xia et al., 2020 [154]	China	169	0.55	x = 59.84y	general	PSQI$_{gen\text{-}sub}$	6
Xiao et al., 2020 (1) [155]	China	170	0.41	x = 37.78y	general	PSQI$_{gen}$	6
Xiao et al., 2020 (2) [156]	China	180	0.72	x = 32.31y	health w.	PSQI$_{gen}$	5
Yang et al., 2020 [157]	China	15,000	0.57	any	general	ISI	5
Yang et al., 2021 [158]	China	388	0.57	18y to > 46y	health w.	PSQI$_{gen}$	5
Yeni et al., 2021 [159]	Turkey	262	0.52	x = 38.08y	general	PSQI$_{gen}$	6
Yin et al., 2020 [160]	China	371	0.62	x = 35.3y	health w.	PSQI$_{sub}$	4
Younes et al., 2021 [161]	Lebanon	4397	0.67	18y to 35y	general	ISI	6
Youssef et al., 2020 [162]	Egypt	540	0.46	x = 37.3y	health w.	ISI	4
Yu et al., 2020 [163]	China	1138	0.66	>18y	general	ISI	6
Yue et al., 2021 [164]	China	31	0.94	18y to 64y	health w.	PSQI$_{gen\text{-}sub}$	5

Table 1 (*continued*)

Author	Country	Sample (n)	Female	Age	Type of pop.	Measure	NOS
Zarzour et al., 2021 (a) [165]	Lebanon	441	1	>18y	health w.	$PSQI_{gen}$	5
Zarzour et al., 2021 (b) [165]	Lebanon	177	0	>18y	health w.	$PSQI_{gen}$	5
Zhang et al., 2020 (1) [166]	China	524	0.75	x = 36.1y	health w.	ISI	4
Zhang et al., 2020 (2a) [167]	China	1255	0.58	any	general	ISI	5
Zhang et al., 2020 (2b) [167]	China	927	0.73	any	health w.	ISI	4
Zhang et al., 2021 [168]	China	319	0.62	x = 30.42y	health w.	$PSQI_{gen}$	4
Zhao et al., 2020 [169]	China	215	0.76	>18y	health w.	$PSQI_{gen\text{-}sub}$	5
Zheng et al., 2021 [170]	China	954	0.62	x = 21.1y	students	ISI	4
Zhou et al., 2020 [171]	China	1931	0.95	x = 35.08y	health w.	$PSQI_{gen\text{-}sub}$	5
Zhou et al., 2021 [172]	China	393	0.80	x = 35.14y	health w.	$PSQI_{gen}$	4
Zhu et al., 2021 [173]	China	114	0.75	x = 32.09y	health w.	$PSQI_{gen}$	5
Zhuo et al., 2020 [174]	China	26	0.46	x = 41.92y	health w.	ISI	4
Zhuo et al., 2021 [175]	China	1017	0.53	>18y	students	ISI	4

Female indicates the relative proportion of female subjects compared to sample size. NOS indicates Newcastle-Ottawa score.

Table 2
Meta-analytic results. The trim and fill procedure was applied in case of statistically significant publication bias.

Measure	k	Random-effect model		Heterogeneity		Publication bias	
		mean	$CI_{95\%}$	Q p-value	I^2 (%)	Begg p-value	Egger p-value
$PSQI_{gen}$	115	6.73	[6.61; 6.85]	<0.001	99.90	0.81	0.17
$PSQI_{c1}$	49	1.20	[1.04; 1.35]	<0.001	99.90	<0.001	<0.001
$PSQI_{c1}$	74	1.70	[1.52; 1.88]	<0.001	99.90	0.03	0.53
$PSQI_{c2}$	46	1.42	[1.27; 1.57]	<0.001	99.70	0.70	0.49
$PSQI_{c3}$	44	0.88	[0.79; 0.98]	<0.001	99.20	0.33	0.02
$PSQI_{c4}$	42	0.76	[0.59; 0.94]	<0.001	99.80	<0.001	<0.01
$PSQI_{c4}$	61	1.24	[1.03; 1.45]	<0.001	99.90	0.27	0.45
$PSQI_{c5}$	47	1.16	[1.03; 1.29]	<0.001	99.80	0.053	0.08
$PSQI_{c6}$	43	0.31	[0.07; 0.55]	<0.001	100.00	<0.001	<0.01
$PSQI_{c6}$	65	1.00	[0.75; 1.25]	<0.001	100.00	0.06	0.60
$PSQI_{c7}$	46	1.13	[0.98; 1.28]	<0.001	99.70	<0.001	<0.01
$PSQI_{c7}$	68	1.57	[1.39; 1.74]	<0.001	99.80	0.14	0.35
ISI	50	8.44	[7.63; 9.26]	<0.001	100.00	0.09	0.25

Table 3
Tests for subgroup differences (random-effects models). RoB = risk of bias.

Measure	k	Study location		Gender		Population		RoB	
		Q (df)	p-value	Q (df)	p-value	Q (df)	p-value	Q (df)	p-value
$PSQI_{gen}$	115	70.80 (6)	<0.001	39.64 (2)	<0.001	12.04 (4)	0.02	9.01 (1)	<0.01
$PSQI_{c1}$	49	17.33 (5)	<0.01	2.00 (2)	0.37	12.98 (4)	0.01	0.20 (1)	0.65
$PSQI_{c2}$	46	129.54 (4)	<0.001	2.94 (2)	0.23	3.35 (3)	0.34	0.10 (1)	0.75
$PSQI_{c3}$	44	3.43 (4)	0.49	0.61 (2)	0.74	41.12 (3)	<0.001	0.18 (1)	0.67
$PSQI_{c4}$	42	0.87 (4)	0.93	2.77 (2)	0.25	1.22 (3)	0.75	0.03 (1)	0.86
$PSQI_{c5}$	47	17.10 (5)	<0.01	0.02 (2)	0.99	5.76 (4)	0.22	0.35 (1)	0.55
$PSQI_{c6}$	4	4.31 (4)	0.37	0.67 (2)	0.72	1.62 (3)	0.65	0.52 (1)	0.47
$PSQI_{c7}$	46	28.56 (5)	<0.001	4.15 (2)	0.13	30.40 (4)	<0.001	5.99 (1)	0.01
ISI	50	106.19 (4)	<0.001	4.60 (2)	0.10	2.49 (2)	0.29	0.00 (1)	0.95

outcomes were predicted by several continuous variables (i.e., female percentage, days, GSI, cases, deaths) by implementing a series of meta-regression analyses. Firstly, we found that $PSQI_{gen}$ was significantly predicted by days with a negative slope (Coef. = −0.002; $p < 0.01$), by female percentage with a positive slope (Coef. = 1.57; $p < 0.001$), and by GSI with a negative slope (Coef. = −2.64; $p < 0.01$). Then, the subcomponent $PSQI_{c1}$ was significantly predicted by GSI with a positive slope (Coef. = 0.94; $p = 0.048$). Meta-regression results are summarized in Table 4. Findings from multimodel inference are reported in Supplementary Document 1.

4. Discussion

This meta-analysis focused on 139 studies, for a total of 137,603 subjects.

Differently from the previous meta-analytic studies [7,8], our study provides a better characterization of subjective sleep alterations during COVID-19 pandemic. More specifically, we considered the prevalence of symptoms according to their geographic distribution, gender, and different populations (general population, children, adolescents, students, health workers). Also, we estimated a quantitative relationship between subjective sleep alterations and gender and pandemic-related measures (i.e., female percentage, days, GSI, cases, deaths).

Among the selected studies, the most used sleep quality measure was PSQI (103 studies), followed by ISI (41 studies). The general mean of PSQI global score was 6.73, indicating poor sleep quality [16]. On the other hand, the mean ISI score was 8.44, resulting in subthreshold insomnia [17]. In other words, during the pandemic period, the subjects reported poor sleep quality, although sleep alterations do not meet the threshold for insomnia.

Table 4
Meta-regression analyses (random-effects model). I^2 values indicate the unexplained between-study heterogeneity.

Measure	Point estimate	female			days			GSI			cases			deaths	
		p-value	I^2 (%)	Point estimate	p-value	I^2 (%)	Point estimate	p-value	I^2 (%)	Point estimate	p-value	I^2 (%)	Point estimate	p-val	I^2 (%)
$PSQI_{gen}$	1.57	<0.001	99.50	−0.002	0.01	99.95	−2.64	<0.01	99.86	0.001	0.46	99.87	−0.02	0.46	99.86
$PSQI_{c1}$	0.32	0.053	99.92	0.000	0.41	99.92	0.94	0.048	99.74	0.001	0.06	99.92	0.02	0.07	99.92
$PSQI_{c2}$	0.45	0.10	99.70	−0.001	0.36	99.70	0.08	0.92	99.61	0.000	0.71	99.70	−0.001	0.96	99.70
$PSQI_{c3}$	−0.09	0.63	99.15	−0.001	0.28	99.17	0.22	0.68	98.97	−0.001	0.30	99.19	−0.01	0.26	99.19
$PSQI_{c4}$	0.17	0.51	99.76	−0.001	0.35	99.60	−0.05	0.94	99.61	0.000	0.97	99.75	−0.003	0.87	99.76
$PSQI_{c5}$	0.02	0.89	99.83	0.000	0.94	99.82	0.49	0.27	99.71	0.001	0.07	99.82	0.01	0.16	99.83
$PSQI_{c6}$	0.08	0.57	99.99	0.000	0.36	99.99	0.23	0.55	99.96	0.000	0.45	99.99	−0.001	0.90	99.99
$PSQI_{c7}$	0.10	0.62	99.68	−0.001	0.07	99.39	−0.26	0.64	99.69	−0.001	0.33	99.62	−0.02	0.10	99.62
ISI	2.47	0.08	99.93	0.01	0.08	99.96	−2.59	0.47	99.96	0.01	0.25	99.94	0.03	0.80	99.94

*The study of Şimşek et al., 2020 [137] is excluded from meta-regression because the author didn't report gender distribution in the paper. GSI = government stringency index.

As regards the characterization of subjective sleep alterations, the subgroup analyses showed that most of the subcategories (geographic distribution, gender, populations, risk of bias) reported poor sleep quality ($PSQI_{gen} > 5$) and subthreshold insomnia (ISI score ranging from 8 to 15). It is worth noting that studies with a low risk of bias – i.e., with a highly representative sample - also go in the same direction, revealing a higher pooled mean in the $PSQI_{gen}$. In other words, we can exclude that our findings may be due to high biased studies with a weak representativeness of the sample since the sleep alterations are generalized in investigations carried out by a more reliable methodological approach.

More in detail, all the countries reported significant sleep impairment and subclinical insomnia, except for Asia (ISI = 6.48). Interestingly, we found that poor sleep quality and higher insomnia scores were prominent in America. It should be considered that most American studies assessing sleep quality were carried out in Brazil or USA, except for three Canadian investigations. Both Brazil and USA have undergone critical conditions during the pandemic causing remarkable deterioration in people's lives. Indeed, these countries registered the highest number of deaths from COVID-19 in the world. Also, it should be hypothesized that countries with a more severe pandemic situation showed greater levels of stress [176] that may impact on sleep quality [177,178].

Additionally, health workers had poorer sleep quality and lower sleep duration than other populations (see Table S1). This result is in line with other reviews and meta-analyses. Healthcare workers are one of the most affected populations by sleep disorders during the pandemic [7,10,12,15,179]. It is well-established that healthcare workers were on the front line of the COVID-19 emergency, working for many hours under extreme stress and for multiple shifts. Moreover, recent results showed that healthcare professionals have a significant prevalence of perceived psychological problems such as stress, anxiety, and depression [179–182] that could exacerbate sleep disturbances.

Our results showed that students have a higher level of daytime dysfunction ($PSQI_{c7}$; see Table S8). Nevertheless, the questions evaluating this sub-component score do not allow to discriminate sleep-related from independent determinants of daytime dysfunction, such as "enthusiasm to get things done." Indeed, the available literature emphasizes the vulnerability of university and college students to psychological distress [183]. In fact, during the pandemic, university and college students have been evicted from campuses or forced abruptly to return home in case of the offsite students. Hence, they experienced a partial interruption of their interpersonal interaction networks and disruption of their daily habits, leading to a high level of feelings of distress [184].

Although both genders reported clinically significant score in $PSQI_{gen}$, subgroup analyses showed that the mean global PSQI score was 6.83 [95% CI 6.56–7.10] among females and 5.57 [5.22–5.92] among males. These results are in line with the prior pandemic literature on the relationship between sleep quality and gender [9,10] and with data indicating that women experience significantly higher stress levels than men during quarantine [176]. During the pandemic, the female gender appeared to be related to higher dream recall frequency and nightmares, that have been interpreted as a reliable inverse index of wellbeing [185,186]. The greater stressors sustained by women during the lockdown were also reflected by an increased prevalence of negative emotions and content in their dreams [187]. Further, males tend to have a later chronotype than females [187], and, to some extent, this would advantage men during the pandemic since they could have a more flexible wake-sleep routine. Besides, some pandemic-related changes concerning the demands due to children's care and family duties may exacerbate sleep problems among women [188].

Accordingly, the meta-regressions revealed that the female percentage is the best predictor of $PSQI_{gen}$. Thus, the larger proportion of women in the sample predict sleep impairment. Also, multimodal inference confirmed that the female percentage is the most influential moderator. Although consistent with the view that women are more likely to suffer from sleep alterations than men during pandemic (e.g., [9,10]), this gender difference could be independent from the pandemic. Firstly, it is worth noting that almost all studies have a greater prevalence of female participants (e.g., [11,135]), which could affect the findings. Second, evidence showed that females had higher "baseline" $PSQI_{gen}$ than males [189], and that women are more likely to experience worse sleep quality and insomnia across many countries [190]. Finally, females are more susceptible to developing psychological distress [191–193] and lower self-reported quality of life [194,195] during wakefulness.

Furthermore, we found that more stringent government measures predict lower global scores at $PSQI_{gen}$, while, albeit to a small extent, less restrictive measures are related to worse subjective sleep quality ($PSQI_{c1}$). Although these findings are apparently in conflict, it should be underlined that $PSQI_{gen}$ is a composite measure that considers different sub-parameters, providing a broader construct of "sleep quality" [16,196]. Differently, $PSQI_{c1}$ represents the global and direct judgment of the subject's sleep quality. Studies employing wrist actigraphy as an objective estimate of sleep showed that during the pandemic sleep was of normal duration [197–199], but more fragmented [199], probably explaining the reduced subjective sleep quality, although no misperception about sleep duration was highlighted [197]. Not surprisingly, the subjective opinion of individuals about their sleep ($PSQI_{c1}$) is more pessimistic than the global composite score $PSQI_{gen}$. This is consistent with the view that subjective evaluations tend to be more influenced by the individuals' beliefs [196]. Also, the general population and the students reported poorer subjective sleep quality than the healthcare workers and the children (see Table S2). We hypothesize that the subjective sleep quality assessed by means of $PSQI_{c1}$ might reflect the negativistic cognitive perspective due to the pandemic situation, children and healthcare workers had probably been less affected by lockdown and mobility restriction measures. In this respect, more stringent requirements and disruption of daily social connections led to increased depression and loneliness [200], that are often characterized by pessimistic thinking [201]. Moreover, we cannot rule out that the self-reported poor sleep quality could be the result of a misperception due to higher psychological distress or specific personality traits [202,203]. The current meta-analysis cannot disentangle this issue since it did not consider psychological factors that could moderate the relationship between the pandemic conditions and sleep patterns.

The inverse association between $PSQI_{gen}$ and less stringent measures might have several possible explanations. First, during a period of more severe restrictions, people might have had the possibility to adapt their sleep-wake schedule to their chronotype rather than to social or working requirements. The reduced impact of social *Zeitgebers* could have positively impacted sleep habits [204]. Second, governmental measures to ensure the safety of people in a period of dramatic uncertainty might have reduced the level of anxiety related to fear of the consequences on health from COVID-19 infection. The easing of restrictions allowed people to go out and start over a relatively ordinary routine after prolonged confinement, and forced people to face the unpleasant emotions related to the risk of infection, possibly causing, in turn, sleep impairment. It could be hypothesized that individuals mostly returned to their pre-pandemic schedules, reducing the positive impact of a sleep-wake schedule partially independent from social and working requirements. According to this view, some findings on dreams during the pandemic revealed that oneiric contents, including crowded places and travels, increased during the post-lockdown period [185]. Moreover, dream experiences during the second wave of pandemic (i.e., partial lockdown) were featured by greater negative emotions than the oneiric activity during Spring 2020 (i.e., total lockdown) [185]. In line with this evidence, a study [205] revealed that fear and negative mood during wakefulness were higher during the partial lockdown than the first full lockdown.

We cannot exclude other factors, such as individuals' resilience, that might impact on the relationship between GSI and sleep quality [206]. Indeed, some results highlighted that people experienced reduced ability to adapt well in the period of low restrictions (second wave of the pandemic) then the total lockdown [207]. Moreover, recent findings highlighted that individuals' adaptability could affect sleep quality [208]. The authors showed that the highly adaptive personalities had less perceived stress and better sleep quality compared to subjects with a lower degree of adaptability [208].

It is worth noting that the effect of COVID-19 on sleep measures may depend on the pre-pandemic individuals' sleep condition. Indeed, a quarter of people with pre-pandemic clinical insomnia experienced a meaningful improvement in sleep quality, whereas 20% of pre-pandemic good sleepers experienced worse sleep during the lockdown measures [209].

Finally, our results showed that the time elapsed since the first COVID-19 case (31 December 2019) is negatively correlated with PSQI global score. Bearing in mind that this variable represents a very weak moderator, this result reveals that the more the survey was filled out near the first announcement of the COVID-19 case, the more people experienced poor sleep quality. This result might be linked to the fear experienced by people at the beginning of the pandemic. In other words, the proximity to the 31 December 2019 is strictly related with the lack of knowledge about the COVID-19 and the absence of weapons to defeat the virus. We might speculate that the availability of SARS-CoV-2 vaccines and new treatments during the different waves of pandemic could have positively affected sleep quality. This finding seems in contrast with the above-mentioned result on the GSI. Nevertheless, it should be underlined that the two variables, "days" and "GSI," are not entirely overlapping, since restrictive measures have been decreased in different moments during the pandemic period.

Several limitations of the present work should be acknowledged. First, we employed a descriptive approach to evaluate the prevalence and diffusion of sleep alterations during the COVID-19 pandemic trying to generalize our findings across different geographic locations, populations, gender, and study quality. Although it is beyond our aims, future studies may dwell on specific subcategories differences by conducting a series of post-hoc analyses. In addition, to provide a more structured approach, we included in our meta-analytic work only four instruments (i.e., PSQI; ISI; MOS-S; ESS) among the most widely used self-reported questionnaires to assess subjective sleep alterations. Since the lack of studies reporting data on MOS-S and ESS, the meta-analysis on the scores of these questionnaires was not conducted. In order to allow more accurate meta-analytic assessment, future investigations should include all the data (mean and SD at least) of the used variables in manuscripts or supplemental materials. Moreover, future studies should include a wider set of questionnaires, as well as other more objective methods. Nevertheless, the studies in the literature employing objective measures of sleep (e.g., actigraphy) are so far very limited. Lastly, another limitation is the large, unexplained heterogeneity (i.e., I^2 values were nearly 100%). The application of the random-effects model, although assumes that the true effect sizes differ from study to study, might be unable to adjust for uncontrolled factors that influence the size of the pooled outcomes. For example, a random-effects meta-analysis weights the studies more equally compared to fixed-effects (i.e., assigns relatively more weight to small studies compared to the weight that such studies would obtain in a fixed-effects model; [210]). Therefore, if findings from smaller studies systematically contrast with larger studies, the aggregated outcomes might be misleading. Nonetheless, even after conducting a series of meta-regressions and subgroup analyses to address potential sources of heterogeneity, the latter remained substantial and significant. Hence, caution in interpreting the present meta-analytic findings is needed. The sizable heterogeneity may be ascribed to the higher number of studies included in the analysis (>100) among which are large epidemiological studies. In meta-analyses with a substantial number of included studies, as suggested by the Cochrane collaboration, formal tests have also high power to detect a trivial amount of heterogeneity [210]. Future studies are warranted to assess the role of other factors, such as psychological variables not considered in this meta-analysis (e.g., anxiety, depression, stress, resilience, …), that may explain the high amount of heterogeneity.

5. Conclusions

This meta-analysis corroborates the finding of recent studies, confirming that sleep quality worsened worldwide during the COVID-19 pandemic, and in the different populations considered in this work: general population, children, students, and healthcare workers. The latter seems to be the population whose sleep quality was most affected during the pandemic. As for pre-pandemic period, women were more prone than men to develop insomnia during COVID-19 emergency.

Moreover, the sub-component analysis of subjective sleep alterations that we performed, based on the PSQI, gives new insights to better understand this phenomenon. We found that, among the populations considered, the students were the ones who reported higher levels of daytime dysfunction. Furthermore, sleep alterations were inversely correlated to the stringency of the governmental measures to face the pandemic and decreased throughout the pandemic.

Our results critically inform further studies on the impact of COVID-19 pandemic on sleep. To disentangle the role of pandemic-related vs. pre-pandemic individuals' factors on sleep, we suggest future studies to perform better clinical profiling of insomnia symptoms, to consider the subjects' psychological profile and coping mechanisms, chronotypes and changes in subject's emotional state. It might also be worthwhile to characterize the impact of the restrictive measures on each subject's life in comparison with the pre-pandemic period. Finally, a combination of subjective and objective measures of sleep would be suitable, for instance using an Ecological Momentary Assessment approach [211], and employing actigraphy, other chronobiologic measures and/or portable polysomnography.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2022.07.012.

References

[1] Altena E, Baglioni C, Espie CA, Ellis J, Gavriloff D, Holzinger B, et al. Dealing with sleep problems during home confinement due to the COVID-19 outbreak: practical recommendations from a task force of the european CBT-I academy. Jo. Sleep Res. 2020;29:e13052. https://doi.org/10.1111/jsr.13052.

[2] Franceschini C, Musetti A, Zenesini C, Palagini L, Scarpelli S, Quattropani MC, et al. Poor sleep quality and its consequences on mental health during the COVID-19 lockdown in Italy. Front Psychol 2020;11:3072. https://doi.org/10.3389/fpsyg.2020.574475.

[3] Casagrande M, Favieri F, Tambelli R, Forte G. The enemy who sealed the world: effects quarantine due to the COVID-19 on sleep quality, anxiety, and psychological distress in the Italian population. Sleep Med 2020;75:12–20. https://doi.org/10.1016/j.sleep.2020.05.011.

[4] Abdulah DM, Musa DH. Insomnia and stress of physicians during COVID-19 outbreak. Sleep Med X 2020;2:100017. https://doi.org/10.1016/j.sleepx.2020.100017.

[5] Beck F, Léger D, Fressard L, Peretti-Watel P, Verger P, Group C. COVID-19 health crisis and lockdown associated with high level of sleep complaints and hypnotic uptake at the population level. Jo. Sleep Res. 2021;30:e13119. https://doi.org/10.1111/jsr.13119.

[6] Hartley S, Colas des Francs C, Aussert F, Martinot C, Dagneaux S, Londe V, et al. The effects of quarantine for SARS-CoV-2 on sleep: an online survey. Encephale 2020;46:S53–9. https://doi.org/10.1016/j.encep.2020.05.003.

[7] Jahrami H, BaHammam AS, Bragazzi NL, Saif Z, Faris M, Vitiello MV. Sleep problems during the COVID-19 pandemic by population: a systematic review and meta-analysis. J Clin Sleep Med 2021;17:299–313. https://doi.org/10.5664/jcsm.8930.

[8] Jahrami HA, Alhaj OA, Humood AM, Alenezi AF, Fekih-Romdhane F, AlRasheed MM, et al. Sleep disturbances during the COVID-19 pandemic: a systematic review, meta-analysis, and meta-regression. Sleep Med Rev 2022:101591. https://doi.org/10.1016/j.smrv.2022.101591.

[9] Alimoradi Z, Broström A, Tsang HW, Griffiths MD, Haghayegh S, Ohayon MM, et al. Sleep problems during COVID-19 pandemic and its' association to psychological distress: a systematic review and meta-analysis. EClinicalMedicine 2021;36:100916. https://doi.org/10.1016/j.eclinm.2021.100916.

[10] Alimoradi Z, Gozal D, Tsang HW, Lin C-Y, Broström A, Ohayon MM, et al. Gender-specific estimates of sleep problems during the COVID-19 pandemic: systematic review and meta-analysis. Jo. Sleep Res. 2022;31:e13432. https://doi.org/10.1111/jsr.13432.

[11] Al Maqbali M, Al Sinani M, Al-Lenjawi B. Prevalence of stress, depression, anxiety and sleep disturbance among nurses during the COVID-19 pandemic: a systematic review and meta-analysis. J Psychosom Res 2021;141:110343. https://doi.org/10.1016/j.jpsychores.2020.110343.

[12] Serrano-Ripoll MJ, Zamanillo-Campos R, Castro A, Fiol-de Roque MA, Ricci-Cabello I. Insomnia and sleep quality in healthcare workers fighting against COVID-19: a systematic review of the literature and meta-analysis. Actas Esp Psiquiatr 2021;49:155–79.

[13] Pappa S, Ntella V, Giannakas T, Giannakoulis VG, Papoutsi E, Katsaounou P. Prevalence of depression, anxiety, and insomnia among healthcare workers during the COVID-19 pandemic: a systematic review and meta-analysis. Brain Behav Immun 2020;88:901–7. https://doi.org/10.1016/j.bbi.2020.05.026.

[14] Xia L, Chen C, Liu Z, Luo X, Guo C, Liu Z, et al. Prevalence of sleep disturbances and sleep quality in Chinese healthcare workers during the COVID-19 pandemic: a systematic review and meta-analysis. Front Psychiatr 2021;12:149. https://doi.org/10.3389/fpsyt.2021.646342.

[15] Salari N, Khazaie H, Hosseinian-Far A, Ghasemi H, Mohammadi M, Shohaimi S, et al. The prevalence of sleep disturbances among physicians and nurses facing the COVID-19 patients: a systematic review and meta-analysis. Glob Health 2020;16:1–4. https://doi.org/10.1186/s12992-020-00620-0.

[16] Buysse DJ, Reynolds III CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatr Res 1989;28:193–213. https://doi.org/10.1016/0165-1781(89)90047-4.

[17] Bastien CH, Vallières A, Morin CM. Validation of the Insomnia Severity Index as an outcome measure for insomnia research. Sleep Med 2001;2:297–307. https://doi.org/10.1016/s1389-9457(00)00065-4.

[18] Soldatos CR, Dikeos DG, Paparrigopoulos TJ. Athens insomnia scale: validation of an instrument based on ICD-10 criteria. J Psychosom Res 2000;48:555–60. https://doi.org/10.1016/S0022-3999(00)00095-7.

[19] Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097. https://doi.org/10.1371/journal.pmed.1000097.

[20] Stewart AL, Ware J. Measuring functioning and well-being: the medical outcomes study approach. Duke University Press; 1992. p. 235–59. https://doi.org/10.7249/CB361.

[21] Johns MW. A new method for measuring daytime sleepiness: the Epworth Sleepiness Scale. Sleep 1991;14:540–5. https://doi.org/10.1093/sleep/14.6.540.

[22] Hale T, Angrist N, Goldszmidt R, Kira B, Petherick A, Phillips T, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). Nat Human Behav 2021;5:529–38. https://doi.org/10.1038/s41562-021-01079-8.

[23] Lo CK-L, Mertz D, Loeb M. Newcastle-Ottawa Scale: comparing reviewers' to authors' assessments. BMC Med Res Methodol 2014;14:1–5. https://doi.org/10.1186/1471-2288-14-45.

[24] Luchini C, Stubbs B, Solmi M, Veronese N. Assessing the quality of studies in meta-analyses: advantages and limitations of the Newcastle ottawa scale. World J Meta-Anal 2017;5:80–4. https://doi.org/10.13105/wjma.v5.i4.80.

[25] Balduzzi S, Rücker G, Schwarzer G. How to perform a meta-analysis with R: a practical tutorial. Evid Base Ment Health 2019;22:153–60. https://doi.org/10.1136/ebmental-2019-300117.

[26] Harrer M, Cuijpers P, Furukawa T, Ebert DD. Dmetar: companion R package for the guide 'doing meta-analysis in R'. *R package version 0.0* 9000. 2019.

[27] DerSimonian R, Laird N. Meta-analysis in clinical trials. Contr Clin Trials 1986;7:177–88. https://doi.org/10.1016/0197-2456(86)90046-2.

[28] Biggerstaff BJ, Jackson D. The exact distribution of Cochran's heterogeneity statistic in one-way random effects meta-analysis. Stat Med 2008;27:6093–110. https://doi.org/10.1002/sim.3428.

[29] Knapp G, Hartung J. Improved tests for a random effects meta-regression with a single covariate. Stat Med 2003;22:2693–710. https://doi.org/10.1002/sim.1482.

[30] Sidik K, Jonkman JN. A simple confidence interval for meta-analysis. Stat Med 2002;21:3153–9. https://doi.org/10.1002/sim.1262.

[31] Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. Br Med J 1997;315:629–34. https://doi.org/10.1136/bmj.315.7109.629.

[32] Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. Biometrics 1994:1088–101.

[33] Duval S, Tweedie R. Trim and fill: a simple funnel-plot–based method of testing and adjusting for publication bias in meta-analysis. Biometrics 2000;56:455–63. https://doi.org/10.1111/j.0006-341X.2000.00455.x.

[34] Cochran WG. Some methods for strengthening the common x^2 tests. Biometrics 1954;10:417–51. https://doi.org/10.2307/3001616.

[35] Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med 2002;21:1539–58. https://doi.org/10.1002/sim.1186.

[36] Harrer M, Cuijpers P, Furukawa TA, Ebert DD. Doing meta-analysis with R: a hands-on guide. Chapman; Hall/CRC; 2021. https://doi.org/10.1201/9781003107347.

[37] Abbas A, Al-Otaibi T, Gheith OA, Nagib AM, Farid MM, Walaa M. Sleep quality among healthcare workers during the COVID-19 pandemic and its impact on medical errors: Kuwait experience. Turkish Thor J 2021;22:142–8. https://doi.org/10.5152/TurkThoracJ.2021.20245.

[38] Abid R, Ammar A, Maaloul R, Souissi N, Hammouda O. Effect of COVID-19-related home confinement on sleep quality, screen time and physical activity in Tunisian boys and girls: a survey. Int J Environ Res Publ Health 2021;18:3065. https://doi.org/10.3390/ijerph18063065.

[39] Akıncı T, Baş, ar HM. Assessment of sleep quality in healthcare workers as part of the COVID-19 outbreak. Turkish JNeurol/Turk Norol Dergisi 2021;27:176–86. https://doi.org/10.4274/tnd.2021.04820.

[40] Akkuş Y, Şahin S, Kanbay Y, Ünlü AA. Determination of the factors affecting sleep quality in the general population during the early phase of the COVID-19 pandemic. J Turk Sleep Med 2021;8:142–50. https://doi.org/10.4274/jtsm.galenos.2021.93063.

[41] Al Maqbali M. Sleep disturbance among frontline nurses during the COVID-19 pandemic. Sleep Biol Rhythm 2021;19:467–73. https://doi.org/10.1007/s41105-021-00337-6.
[42] Al-Musharaf S, Aljuraiban G, Bogis R, Alnafisah R, Aldhwayan M, Tahrani A. Lifestyle changes associated with COVID-19 quarantine among young Saudi women: a prospective study. PLoS One 2021;16:e0250625. https://doi.org/10.1371/journal.pone.0250625.
[43] Alfonsi V, Gorgoni M, Scarpelli S, Zivi P, Sdoia S, Mari E, et al. COVID-19 lockdown and poor sleep quality: not the whole story. J Sleep Res 2021:e13368. https://doi.org/10.1111/jsr.13368.
[44] AlGhufli F, AlMulla R, Alyedi O, AlAbdin SZ, Nakhal MM. Investigating the impact of COVID-19 pandemic on mental health status and factors influencing negative mental health among health-care workers in Dubai, United Arab Emirates. Dubai Med J 2021;4:231–9. https://doi.org/10.1159/000518717.
[45] Alharbi WI, Mahrus A, Elsayed S, Alolayan AB. Sleep quality among nurses during the first year of Coronavirus disease 2019. Open Acc Maced J Med Sci 2021;9:128–34. https://doi.org/10.3889/oamjms.2021.6923.
[46] Alharbi AS, Alshahrani SM, Alsaadi MM, Al-Jahdali HH, Wali SO, BaHammam AS. Sleep quality and insomnia during the COVID-19 lockdown among the Saudi public. Saudi Med J 2021;42:384–90. https://doi.org/10.15537/smj.2021.42.4.20200735.
[47] Ali M, Uddin Z, Ahsan NF, Haque MZ, Bairagee M, Khan SA, et al. Prevalence of mental health symptoms and its effect on insomnia among healthcare workers who attended hospitals during COVID-19 pandemic: a survey in Dhaka city. Heliyon 2021;7:e06985. https://doi.org/10.1016/j.heliyon.2021.e06985.
[48] Alqahtani SS, Banji D, Banji OJ. A survey assessing sleep efficiency among saudis during COVID-19 home confinement using the Pittsburgh Sleep Quality Index: a call for health education. Saudi Pharmaceut J 2021;29:692–8. https://doi.org/10.1016/j.jsps.2021.04.031.
[49] AlRasheed MM, Alkadir AM, Shuqiran KIB, Al-Aqeel S, Jahrami HA, BaHammam AS. The impact of quarantine on sleep quality and psychological distress during the COVID-19 pandemic. Nat Sci Sleep 2021;13:1037–48. https://doi.org/10.2147/NSS.S313373.
[50] Amra B, Salmasi M, Soltaninejad F, Sami R, Nickpour M, Mansourian M, et al. Healthcare workers' sleep and mood disturbances during COVID-19 outbreak in an Iranian referral center. Sleep Breath 2021:1–8. https://doi.org/10.1007/s11325-021-02312-4.
[51] Assenza G, Lanzone J, Brigo F, Coppola A, Di Gennaro G, Di Lazzaro V, et al. Epilepsy care in the time of COVID-19 pandemic in Italy: risk factors for seizure worsening. Front Neurol 2020;11. https://doi.org/10.3389/fneur.2020.00737.
[52] Banthiya S, Sharma S, Jahagirdar D, Jahagirdar V, Garg M, Sahadev H. Sleep quality in the Indian adult population during the COVID-19 pandemic. Cureus 2021;13:e17535. https://doi.org/10.7759/cureus.17535.
[53] Barrea L, Pugliese G, Framondi L, Di Matteo R, Laudisio D, Savastano S, et al. Does Sars-Cov-2 threaten our dreams? Effect of quarantine on sleep quality and Body Mass Index. J Transl Med 2020;18. https://doi.org/10.1186/s12967-020-02465-y.
[54] Bartoszek A, Walkowiak D, Bartoszek A, Kardas G. Mental well-being (depression, loneliness, insomnia, daily life fatigue) during COVID-19 related home-confinement—a study from Poland. Int J Environ Res Publ Health 2020;17:7417. https://doi.org/10.3390/ijerph17207417.
[55] Başkan SA, Güneş D. The effect of stress perceived by adults due to the COVID-19 pandemic on their sleep quality. J Turk Sleep Med 2021;1:57–66. https://doi.org/10.4274/jtsm.galenos.2021.02996.
[56] Bazzani A, Bruno S, Frumento P, Cruz-Sanabria F, Turchetti G, Faraguna U. Sleep quality mediates the effect of chronotype on resilience in the time of COVID-19. Chronobiol Int 2021;38:883–92. https://doi.org/10.1080/07420528.2021.1895199.
[57] Bhat BA, Mir RA, Hussain A, Shah IR. Depressive and anxiety symptoms, quality of sleep, and coping during the 2019 Coronavirus disease pandemic in general population in Kashmir. Mid East Cur Psych 2020;27(1). https://doi.org/10.1186/s43045-020-00069-2.
[58] Ş Bilgiç, Çelikkalp Ü, Mısırlı C. Stress level and sleep quality of nurses during the COVID-19 pandemic. Work 2021;1–9. https://doi.org/10.3233/WOR-210538.
[59] Bücker J, Rosa AR, Czepielewski LS. Impact of the COVID-19 pandemic on mental health among local residents in south of Brazil: during pandemic times, youth sleep matters. Trends Psychiatr. Psychother. 2021. https://doi.org/10.47626/2237-6089-2021-0225.
[60] Cellini N, Canale N, Mioni G, Costa S. Changes in sleep pattern, sense of time and digital media use during COVID-19 lockdown in Italy. Jo. Sleep Res. 2020:e13074. https://doi.org/10.1111/jsr.13074.
[61] Chen L, Lin D, Feng H. An investigation of mental health status among medical staff following COVID-19 outbreaks: a cross-sectional study. Med Sci Mon Int Med J Exp Clin Res: Int Med J Exper Clinic Res 2021;27:e929454. https://doi.org/10.12659/MSM.929454.
[62] Chen F, Zhan W, Hong'en Xu YW, Jia Y, Liang X, Chen W. Changes in the psychological state of medical personnel in the department of radiotherapy at a tertiary care teaching hospital in China during the epidemic. Ann Work Exp Health 2021;1–5. https://doi.org/10.1093/annweh/wxab015.
[63] Cheng F-F, Zhan S-H, Xie A-W, Cai S-Z, Hui L, Kong X-X, et al. Anxiety in Chinese pediatric medical staff during the outbreak of Coronavirus disease 2019: a cross-sectional study. Transl Pediatr 2020;9:231–6. https://doi.org/10.21037/tp.2020.04.02.
[64] Cheng P, Casement MD, Cuellar R, Johnson DA, Kalmbach D, Cuamatzi Castelan A, et al. Sleepless in COVID-19: racial disparities during the pandemic as a consequence of structural inequity. Sleep Res Soc 2021:1. https://doi.org/10.1093/sleep/zsab242.
[65] Conte F, De Rosa O, Rescott ML, Arabia TP, D'Onofrio P, Lustro A, et al. High sleep fragmentation parallels poor subjective sleep quality during the third wave of the COVID-19 pandemic: an actigraphic study. J Sleep Res 2021:e13519. https://doi.org/10.1111/jsr.13519.
[66] Conte F, Cellini N, De Rosa O, Rescott ML, Malloggi S, Giganti F, et al. Dissociated profiles of sleep timing and sleep quality changes across the first and second wave of the COVID-19 pandemic. J Psychiatr Res 2021;143:222–9. https://doi.org/10.1016/j.jpsychires.2021.09.025.
[67] Costa C, Teodoro M, Briguglio G, Vitale E, Giambò F, Indelicato G, et al. Sleep quality and mood state in resident physicians during COVID-19 pandemic. Int J Environ Res Publ Health 2021;18:8023. https://doi.org/10.3390/ijerph18158023.
[68] Czenczek-Lewandowska E, Wyszyńska J, Leszczak J, Baran J, Weres A, Mazur A, et al. Health behaviours of young adults during the outbreak of the COVID-19 pandemic - a longitudinal study. BMC Publ Health 2021;21:1038. https://doi.org/10.1186/s12889-021-11140-w.
[69] Dale R, Budimir S, Probst T, Stippl P, Pieh C. Mental health during the COVID-19 lockdown over the christmas period in Austria and the effects of sociodemographic and lifestyle factors. Int J Environ Res Publ Health 2021;18:3679. https://doi.org/10.3390/ijerph18073679.
[70] Demartini B, Nisticò V, D'Agostino A, Priori A, Gambini O. Early psychiatric impact of COVID-19 pandemic on the general population and healthcare workers in Italy: a preliminary study. Front Psychiatr 2020;11:561345. https://doi.org/10.3389/fpsyt.2020.561345.
[71] Ding X, Yao J. Peer education intervention on adolescents' anxiety, depression, and sleep disorder during the COVID-19 pandemic. Psychiatr Danub 2020;32:527–35. https://doi.org/10.24869/psyd.2020.527.
[72] Du C, Zan MCH, Cho MJ, Fenton JI, Hsiao PY, Hsiao R, et al. The effects of sleep quality and resilience on perceived stress, dietary behaviors, and alcohol misuse: a mediation-moderation analysis of higher education students from asia, europe and north America during the COVID-19 pandemic. Nutrients 2021;13:442. https://doi.org/10.3390/nu13020442.
[73] Duran S, Ö Erkin. Psychologic distress and sleep quality among adults in Turkey during the COVID-19 pandemic. Prog Neuro Psychopharmacol Biol Psychiatr 2021;107:110254. https://doi.org/10.1016/j.pnpbp.2021.110254.
[74] Engin CD, Kara BS, Ozturk T, Dadas OF. The impact of COVID-19 pandemic on practice patterns and psychological status of ophthalmologists in Turkey. Cureus 2021;13:e16614. https://doi.org/10.7759/cureus.16614.
[75] Eleftheriou A, Rokou A, Arvaniti A, Nena E, Steiropoulos P. Sleep quality and mental health of medical students in Greece during the COVID-19 pandemic. Front Public Health 2021;9:775374. https://doi.org/10.3389/fpubh.2021.775374.
[76] Elhadi M, Alsoufi A, Msherghi A, Alshareea E, Ashini A, Nagib T, et al. Psychological health, sleep quality, behavior, and internet use among people during the COVID-19 pandemic: a cross-sectional study. Front Psychiatr 2021;12:632496. https://doi.org/10.3389/fpsyt.2021.632496.
[77] Fidanci I, Güleryüz Okş an, derinöz, Fidanci I. An analysis on sleep quality of the healthcare professionals during the COVID-19 pandemic. Acta Med 2020;36:3797. https://doi.org/10.19193/0393-6384_2020_6_601.
[78] Forte G, Favieri F, Tambelli R, Casagrande M. COVID-19 pandemic in the Italian population: validation of a post-traumatic stress disorder questionnaire and prevalence of PTSD symptomatology. Int J Environ Res Publ Health 2020;17:4151. https://doi.org/10.3390/ijerph17114151.
[79] Gao C, Scullin MK. Sleep health early in the coronavirus disease 2019 (COVID-19) outbreak in the United States: integrating longitudinal, cross-sectional, and retrospective recall data. Sleep Med 2020;73:1. https://doi.org/10.1016/j.sleep.2020.06.032.
[80] Gargiulo AT, Peterson LM, Grafe LA. Stress, coping, resilience, and sleep during the COVID-19 pandemic: a representative survey study of US adults. Brain and Behavior 2021;11:e2384. https://doi.org/10.1002/brb3.2384.
[81] Genta FD, Rodrigues Neto GB, Sunfeld JPV, Porto JF, Xavier AD, Moreno CR, et al. COVID-19 pandemic impact on sleep habits, chronotype, and health-related quality of life among high school students: a longitudinal study. J Clin Sleep Med 2021;17:1371–7. https://doi.org/10.5664/jcsm.9196.
[82] Gorgoni M, Scarpelli S, Mangiaruga A, Alfonsi V, Bonsignore MR, Fanfulla F, et al. Persistence of the effects of the COVID-19 lockdown on sleep: a longitudinal study. Brain Sci 2021;11:1520. https://doi.org/10.3390/brainsci11111520.
[83] Gorgoni M, Scarpelli S, Alfonsi V, Annarumma L, Cordone S, Stravolo S, et al. Pandemic dreams: quantitative and qualitative features of the oneiric activity during the lockdown due to COVID-19 in Italy. Sleep Med 2021;81:20–32. https://doi.org/10.1016/j.sleep.2021.02.006.
[84] Gu S, He Z, Sun L, Jiang Y, Xu M, Feng G, et al. Effects of Coronavirus-19 induced loneliness on mental health: sleep quality and intolerance for uncertainty as mediators. Front Psychiatr 2021;12:738003. https://doi.org/10.3389/fpsyt.2021.738003.
[85] Hao F, Tan W, Jiang L, Zhang L, Zhao X, Zou Y, et al. Do psychiatric patients experience more psychiatric symptoms during COVID-19 pandemic and lockdown? A case-control study with service and research implications for

immunopsychiatry. Brain Behav Immun 2020;87:100–6. https://doi.org/10.1016/j.bbi.2020.04.069.
[86] Harriger JA, Joseph NT, Trammell J. Detrimental associations of cumulative trauma, COVID-19 infection indicators, avoidance, and loneliness with sleep and negative emotionality in emerging adulthood during the pandemic. Emerg Adulthood 2021;1–3. https://doi.org/10.1177/21676968211022594.
[87] Helito AC, Lindoso L, Sieczkowska SM, Astley C, Queiroz LB, Rose N, et al. Poor sleep quality and health-related quality of life impact in adolescents with and without chronic immunosuppressive conditions during COVID-19 quarantine. Clinics 2021;76:e3501. https://doi.org/10.6061/clinics/2021/e3501.
[88] Huang Y, Wang Y, Zeng L, Yang J, Song X, Rao W, et al. Prevalence and correlation of anxiety, insomnia and somatic symptoms in a Chinese population during the COVID-19 epidemic. Front Psychiatr 2020;11:894. https://doi.org/10.3389/fpsyt.2020.568329.
[89] Huang Y, Zhou Y, Wei Y, Zeng L, Yang J, Li Y, et al. Differences in the association of anxiety, insomnia and somatic symptoms between medical staff and the general population during the outbreak of COVID-19. Neuropsychiatric Dis Treat 2021;17:1907–15. https://doi.org/10.2147/NDT.S300719.
[90] Huang X, Liang Y, Eli B, Yang Y, Han R, Liu Z. Mental health of staff in a key frontline hospital during COVID-19: a single-center cross-sectional China-based study. Asia Pac J Publ Health 2021:1–33. https://doi.org/10.1177/10105395211014703.
[91] Jahrami H, BaHammam AS, AlGahtani H, Ebrahim A, Faris M, AlEid K, et al. The examination of sleep quality for frontline healthcare workers during the outbreak of COVID-19. Sleep Breath 2020;25:503–11. https://doi.org/10.1007/s11325-020-02135-9.
[92] Jamieson D, Kannis-Dymand L, Beaudequin DA, Schwenn P, Shan Z, McLoughlin LT, et al. Can measures of sleep quality or white matter structural integrity predict level of worry or rumination in adolescents facing stressful situations? Lessons from the COVID-19 pandemic. J Adolesc 2021;91:110–8. https://doi.org/10.1016/j.adolescence.2021.08.002.
[93] Jiang Y-F, Chen J-Q, Wang Y-G, Zhang X-D, Hong W-K. Sleep quality and mental health status of healthcare professionals during the outbreak of Coronavirus disease 2019 (COVID-19). Psychol Health Med 2021:1–8. https://doi.org/10.1080/13548506.2021.1954669.
[94] Jin L-R, Zhou S, Yuan H. Investigation on sleep quality in Chinese medical staff during the COVID-19 pandemic. Psychol Health Med 2021:1–7. https://doi.org/10.1080/13548506.2021.1922722.
[95] Kandemir D, Temiz Z, Ozhanli Y, Erdogan H, Kanbay Y. Analysis of mental health symptoms and insomnia levels of intensive care nurses during the COVID-19 pandemic with a structural equation model. J Clin Nurs 2021. https://doi.org/10.1111/jocn.15918.
[96] Khan HR, Ashraf F, Ullah I, Tahir MJ, Dominari A, Shoib S, et al. Cross-cultural prevalence of sleep quality and psychological distress in healthcare workers during COVID-19 pandemic. Brain and Behavior 2021;11:e2383. https://doi.org/10.1002/brb3.2383.
[97] Kim-Godwin YS, Lee MH, Logan JG, Liu X. Factors influencing sleep quality among female staff nurses during the early COVID-19 pandemic in the United States. Int J Environ Res Publ Health 2021;18:4827. https://doi.org/10.3390/ijerph18094827.
[98] Korkmaz S, Kazgan A, Çekiç S, Tartar AS, Balcı HN, Atmaca M. The anxiety levels, quality of sleep and life and problem-solving skills in healthcare workers employed in COVID-19 services. J Clin Neurosci 2020;80:131–6. https://doi.org/10.1016/j.jocn.2020.07.073.
[99] Krupa S, Filip D, Mędrzycka-Dabrowska W, Lewandowska K, Witt P, Ozga D. Sleep disorders among nurses and other health care workers in Poland during the COVID-19 pandemic. Appl Nurs Res 2021;59:151412. https://doi.org/10.1016/j.apnr.2021.151412.
[100] Lai AY, Lee L, Wang M, Feng Y, Lai TT, Ho L, et al. Mental health impacts of the COVID-19 pandemic on international university students, related stressors, and coping strategies. Front Psychiatr 2020;11:584240. https://doi.org/10.3389/fpsyt.2020.584240.
[101] Lam CS, Yu BY-M, Cheung DST, Cheung T, Lam SC, Chung K-F, et al. Sleep and mood disturbances during the COVID-19 outbreak in an urban Chinese population in Hong Kong: a longitudinal study of the second and third waves of the outbreak. Int J Environ Res Publ Health 2021;18:8444. https://doi.org/10.3390/ijerph18168444.
[102] Lin Y-Q, Lin Z-X, Wu Y-X, Wang L, Zeng Z-N, Chen Q-Y, et al. Reduced sleep duration and sleep efficiency were independently associated with frequent nightmares in Chinese frontline medical workers during the coronavirus disease 2019 outbreak. Front Neurosci 2021;14:631025. https://doi.org/10.3389/fnins.2020.631025.
[103] Lin Y, Liu S, Li S, Zuo H, Zhang B. Relationships between the changes in sleep patterns and sleep quality among Chinese people during the 2019 coronavirus disease outbreak. Sleep Med 2021. https://doi.org/10.1016/j.sleep.2021.01.021.
[104] Lin L, Wang J, Ou-Yang X-Y, Miao Q, Chen R, Liang F, et al. The immediate impact of the 2019 novel coronavirus (COVID-19) outbreak on subjective sleep status. Sleep Med 2021;77:348–54. https://doi.org/10.1016/j.sleep.2020.05.018.
[105] Liu D, Liu S, Zhu L, Li D, Huang D, Deng H, et al. Prevalence and related factors of insomnia among Chinese medical staff in the middle and late stage of COVID-19. Front Psychiatr 2020;11:602315. https://doi.org/10.3389/fpsyt.2020.602315.
[106] Liu B, Qiao K, Lu Y. The relationship between perceived stress, state-trait anxiety, and sleep quality among university graduates in China during the COVID-19 pandemic. Front Psychol 2021;12:664780. https://doi.org/10.3389/fpsyg.2021.664780.
[107] Liu Y, Jiang T, Shi T, Liu Y, Liu X, Xu G, et al. The effectiveness of diaphragmatic breathing relaxation training for improving sleep quality among nursing staff during the COVID-19 outbreak: a before and after study. Sleep Med 2021;78:8–14. https://doi.org/10.1016/j.sleep.2020.12.003.
[108] Luo L, Song N, Yang H, Huang J, Zhou L, Zhang L. Intervention effect of long-term aerobic training on anxiety, depression, and sleep quality of middle school students with depression after COVID-19. Front Psychiatr 2021;12:720833. https://doi.org/10.3389/fpsyt.2021.720833.
[109] Maestro-Gonzalez A, Sánchez-Zaballos M, Mosteiro-Dıaz MP, Zuazua-Rico D. Quality of sleep among social media users during the lockdown period due to COVID-19 in Spain. Sleep Med 2021;80:210–5. https://doi.org/10.1016/j.sleep.2021.01.050.
[110] Marelli S, Castelnuovo A, Somma A, Castronovo V, Mombelli S, Bottoni D, et al. Impact of COVID-19 lockdown on sleep quality in university students and administration staff. J Neurol 2021;268:8–15. https://doi.org/10.1007/s00415-020-10056-6.
[111] Martın J, Á Padierna, Villanueva A, Quintana JM. Evaluation of the mental health of care home staff in the COVID-19 era. What price did care home workers pay for standing by their patients? Int J Geriatr Psychiatr 2021;36(11):1810–9. https://doi.org/10.1002/gps.5602.
[112] Martın J, Á Padierna, Villanueva A, Quintana JM. Evaluation of the mental health of health professionals in the COVID-19 era. What mental health conditions are our health care workers facing in the new wave of coronavirus? Int J Clin Pract 2021:e14607. https://doi.org/10.1111/ijcp.14607.
[113] Martınez-de-Quel Ó, Suárez-Iglesias D, López-Flores M, Pérez CA. Physical activity, dietary habits and sleep quality before and during COVID-19 lockdown: a longitudinal study. Appetite 2021;158:105019. https://doi.org/10.1016/j.appet.2020.105019.
[114] Martınez-Lezaun I, Santamarıa-Vázquez M, Del Lıbano M. Influence of confinement by COVID-19 on the quality of sleep and the interests of university students. Nat Sci Sleep 2020;12:1075–81. https://doi.org/10.2147/NSS.S280892.
[115] Meo SA, Alkhalifah JM, Alshammari NF, Alnufaie WS. Comparison of generalized anxiety and sleep disturbance among frontline and second-line healthcare workers during the COVID-19 pandemic. Int J Environ Res Publ Health 2021;18:5727. https://doi.org/10.3390/ijerph18115727.
[116] Milasauskiene E, Burkauskas J, Podlipskyte A, Király O, Demetrovics Z, Ambrasas L, et al. Compulsive internet use scale: psychometric properties and associations with sleeping patterns, mental health, and well-being in Lithuanian medical students during the Coronavirus disease 2019 pandemic. Front Psychol 2021;12:685137. https://doi.org/10.3389/fpsyg.2021.685137.
[117] Miranda AR, Scotta AV. Triggering of postpartum depression and insomnia with cognitive impairment in Argentinian women during the pandemic COVID-19 social isolation in relation to reproductive and health factors. Midwifery 2021;102:103072. https://doi.org/10.1016/j.midw.2021.103072.
[118] Mousavi M, Ahmadi N, Ghaheh HS, Vaezi A, Javanmard SH. Psychological impact of COVID-19 on health-care workers: a multicenter cross-sectional study. J Res Med Sci: Off J Isfahan Univ Med Sci 2021;26:77. https://doi.org/10.4103/jrms.JRMS_1046_20.
[119] Olagunju AT, Bioku AA, Olagunju TO, Sarimiye FO, Onwuameze OE, Halbreich U. Psychological distress and sleep problems in healthcare workers in a developing context during COVID-19 pandemic: implications for workplace wellbeing. Prog Neuro Psychopharmacol Biol Psychiatr 2021;110:110292. https://doi.org/10.1016/j.pnpbp.2021.110292.
[120] Peng M, Mo B, Liu Y, Xu M, Song X, Liu L, et al. Prevalence, risk factors and clinical correlates of depression in quarantined population during the COVID-19 outbreak. J Affect Disord 2020;275:119–24. https://doi.org/10.1016/j.jad.2020.06.035.
[121] Pieh C, Budimir S, Humer E, Probst T. Comparing mental health during the COVID-19 lockdown and 6 months after the lockdown in Austria: a longitudinal study. Front Psychiatr 2021;12:625973. https://doi.org/10.3389/fpsyt.2021.625973.
[122] Qi J, Xu J, Li B-Z, Huang J-S, Yang Y, Zhang Z-T, et al. The evaluation of sleep disturbances for Chinese frontline medical workers under the outbreak of COVID-19. Sleep Med 2020;72:1–4. https://doi.org/10.1016/j.sleep.2020.05.023.
[123] Robillard R, Dion K, Pennestri M-H, Solomonova E, Lee E, Saad M, et al. Profiles of sleep changes during the COVID-19 pandemic: demographic, behavioural and psychological factors. Jo. Sleep Res. 2021;30(1):e13231. https://doi.org/10.1111/jsr.13231.
[124] Romero-Blanco C, Rodrıguez-Almagro J, Onieva-Zafra MD, Parra-Fernández ML, Prado-Laguna M del C, Hernández-Martınez A. Sleep pattern changes in nursing students during the COVID-19 lockdown. Int J Environ Res Publ Health 2020;17:5222. https://doi.org/10.3390/ijerph17145222.
[125] Saadeh H, Saadeh M, Almobaideen W, Al Refaei A, Shewaikani N, Al Fayez RQ, et al. Effect of COVID-19 quarantine on the sleep quality and the depressive symptom levels of university students in Jordan during the spring of 2020. Front Psychiatr 2021;12:605676. https://doi.org/10.3389/fpsyt.2021.605676.
[126] Sagherian K, Steege LM, Cobb SJ, Cho H. Insomnia, fatigue and psychosocial well-being during COVID-19 pandemic: a cross-sectional survey of hospital

nursing staff in the United States. J Clin Nurs 2020:1–4. https://doi.org/10.1111/jocn.15566.
[127] Sahin SK, Arslan E, Atalay ÜM, Demir B, Elboga G, Altındağ A. Psychological impact of COVID-19 outbreak on health workers in a university hospital in Turkey. Psychol Health Med 2021:1. https://doi.org/10.1080/13548506.2021.1900578.
[128] Salfi F, Lauriola M, Amicucci G, Corigliano D, Viselli L, Tempesta D, et al. Gender-related time course of sleep disturbances and psychological symptoms during the COVID-19 lockdown: a longitudinal study on the Italian population. Neurobiol Stress 2020;13:100259. https://doi.org/10.1016/j.ynstr.2020.100259.
[129] San Martin AH, Serrano JP, Cambriles TD, Arias EMA, Méndez JM, Yerro Álvarez MJ del, et al. Sleep characteristics in health workers exposed to the COVID-19 pandemic. Sleep Med 2020;75:388–94. https://doi.org/10.1016/j.sleep.2020.08.013.
[130] Santos J, Lima C, Moreira W, Monteiro P, Sales M, Lima J, et al. The quality of sleep of physiotherapists in a public hospital during the COVID-19 pandemic. Rev Pesqui Fisioterapia 2021;11:510–7. https://doi.org/10.17267/2238-2704rpf.v11i3.3911.
[131] Sañudo B, Fennell C, Sánchez-Oliver AJ. Objectively-assessed physical activity, sedentary behavior, smartphone use, and sleep patterns pre-and during-COVID-19 quarantine in young adults from Spain. Sustainability 2020;12:5890. https://doi.org/10.3390/su12155890.
[132] Saracoglu KT, Simsek T, Kahraman S, Bombaci E, Sezen Ö, Saracoglu A, et al. The psychological impact of COVID-19 disease is more severe on intensive care unit healthcare providers: a cross-sectional study. Clinic Psychopharm Neurosci 2020;18:607–15. https://doi.org/10.9758/cpn.2020.18.4.607.
[133] Scotta AV, Cortez MV, Miranda AR. Insomnia is associated with worry, cognitive avoidance and low academic engagement in Argentinian university students during the COVID-19 social isolation. Psychol Health Med 2020;1–6. https://doi.org/10.1080/13548506.2020.1869796.
[134] Sella E, Carbone E, Toffalini E, Borella E. Self-reported sleep quality and dysfunctional sleep-related beliefs in young and older adults: changes in times of COVID-19 lockdown. Sleep Med 2021;81:127–35. https://doi.org/10.1016/j.sleep.2021.02.017.
[135] Shillington KJ, Vanderloo LM, Burke SM, Ng V, Tucker P, Irwin JD. Not so sweet dreams: adults' quantity, quality, and disruptions of sleep during the initial stages of the COVID-19 pandemic. Sleep Med 2021. https://doi.org/10.1016/j.sleep.2021.02.028.
[136] Shrestha D, Adhikari SP, Rawal N, Budhathoki P, Pokharel S, Adhikari Y, et al. Sleep quality among undergraduate students of a medical college in Nepal during COVID-19 pandemic: an online survey. F1000Research 2021;10:505. https://doi.org/10.12688/f1000research.53904.2.
[137] Şimşek E, Koç K, Özsoy D, Karakuş M. Investigation the effect of performing physical activity at home on sleep quality and life satisfaction during coronavirus (COVID-19) outbreak. Int J Appl Exerc Physiol 2020;9:55–62.
[138] Siste K, Hanafi E, Sen LT, Murtani BJ, Christian H, Limawan AP, et al. Implications of COVID-19 and lockdown on internet addiction among adolescents: data from a developing country. Front Psychiatr 2021;12:665675. https://doi.org/10.3389/fpsyt.2021.665675.
[139] Solon Júnior LJF, Ribeiro CHT, Fortes L de S, Barbosa BT, Silva Neto LV da. Smartphone addiction is associated with symptoms of anxiety, depression, stress, tension, confusion, and insomnia: a cross-sectional and comparative study with physically and non-physically active adults in self-isolation during the COVID-19 pandemic. Salud Ment 2021;44:193–200. https://doi.org/10.17711/SM.0185-3325.2021.025.
[140] Soylu Y. The psychophysiological effects of the COVID-19 quarantine in the college students. Phys Ed Stud 2021;25:158–63. https://doi.org/10.15561/20755279.2021.0303.
[141] Tahir MJ, Malik NI, Ullah I, Khan HR, Perveen S, Ramalho R, et al. Internet addiction and sleep quality among medical students during the COVID-19 pandemic: a multinational cross-sectional survey. PLoS One 2021;16:e0259594. https://doi.org/10.1371/journal.pone.0259594.
[142] Tan W, Hao F, McIntyre RS, Jiang L, Jiang X, Zhang L, et al. Is returning to work during the COVID-19 pandemic stressful? A study on immediate mental health status and psychoneuroimmunity prevention measures of Chinese workforce. Brain Behav Immun 2020;87:84–92. https://doi.org/10.1016/j.bbi.2020.04.055.
[143] Targa AD, Benıtez ID, Moncusı-Moix A, Arguimbau M, Batlle J de, Dalmases M, et al. Decrease in sleep quality during COVID-19 outbreak. Sleep Breath 2020;25:1055–61. https://doi.org/10.1007/s11325-020-02202-1.
[144] Trabelsi K, Ammar A, Masmoudi L, Boukhris O, Chtourou H, Bouaziz B, et al. Sleep quality and physical activity as predictors of mental wellbeing variance in older adults during COVID-19 lockdown: ECLB COVID-19 international online survey. Int J Environ Res Publ Health 2021;18:4329. https://doi.org/10.3390/ijerph18084329.
[145] Trabelsi K, Ammar A, Masmoudi L, Boukhris O, Chtourou H, Bouaziz B, et al. Globally altered sleep patterns and physical activity levels by confinement in 5056 individuals: ECLB COVID-19 international online survey. Biol Sport 2021;38:495–506. https://doi.org/10.5114/biolsport.2021.101605.
[146] Tu Z, He J, Zhou N. Sleep quality and mood symptoms in conscripted frontline nurse in Wuhan, China during COVID-19 outbreak: a cross-sectional study. Medicine 2020;99:e20769. https://doi.org/10.1097/MD.0000000000020769.
[147] Verma S, Donovan J, Tunuguntla HS, Tunuguntla R, Gupta BV, Nandi A, et al. Yoga of immortals intervention reduces symptoms of depression, insomnia and anxiety. Front Psychiatr 2021;12:648029. https://doi.org/10.3389/fpsyt.2021.648029.
[148] Wang X, Jiang X, Huang Q, Wang H, Gurarie D, Ndeffo-Mbah M, et al. Risk factors of SARS-CoV-2 infection in healthcare workers: a retrospective study of a nosocomial outbreak. Sleep Med X 2020;2:100028. https://doi.org/10.1016/j.sleepx.2020.100028.
[149] Wang S, Xie L, Xu Y, Yu S, Yao B, Xiang D. Sleep disturbances among medical workers during the outbreak of COVID-2019. Occup Med-c 2020;70:364–9. https://doi.org/10.1093/occmed/kqaa074.
[150] Wang J, Gong Y, Chen Z, Wu J, Feng J, Yan S, et al. Sleep disturbances among Chinese residents during the Coronavirus disease 2019 outbreak and associated factors. Sleep Med 2020;74:199–203. https://doi.org/10.1016/j.sleep.2020.08.002.
[151] Wilson D, Driller M, Johnston B, Gill N. The effectiveness of a 17-week lifestyle intervention on health behaviors among airline pilots during COVID-19. J Sport and Health Sci 2021;10:333–40. https://doi.org/10.1016/j.jshs.2020.11.007.
[152] Wong SYS, Zhang D, Sit RWS, Yip BHK, Chung RY, Wong CKM, et al. Impact of COVID-19 on loneliness, mental health, and health service utilisation. Br J Gen Pract 2020. https://doi.org/10.3399/bjgp20X713021.
[153] Wu K, Wei X. Analysis of psychological and sleep status and exercise rehabilitation of front-line clinical staff in the fight against COVID-19 in China. Med Sci Monitor Basic Res 2020;26:e924085. https://doi.org/10.12659/MSMBR.924085.
[154] Xia Y, Kou L, Zhang G, Han C, Hu J, Wan F, et al. Investigation on sleep and mental health of patients with Parkinson's disease during the Coronavirus disease 2019 pandemic. Sleep Med 2020;75:428–33. https://doi.org/10.1016/j.sleep.2020.09.011.
[155] Xiao H, Zhang Y, Kong D, Li S, Yang N. Social capital and sleep quality in individuals who self-isolated for 14 days during the coronavirus disease 2019 (COVID-19) outbreak in january 2020 in China. Med Sci Mon Int Med J Exp Clin Res: Int Med J Exper Clinic Res 2020;26:e923921. https://doi.org/10.12659/MSM.923921.
[156] Xiao H, Zhang Y, Kong D, Li S, Yang N. The effects of social support on sleep quality of medical staff treating patients with Coronavirus disease 2019 (COVID-19) in January and February 2020 in China. Med Sci Mon Int Med J Exp Clin Res: Int Med J Exper Clinic Res 2020;26:e923549. https://doi.org/10.12659/MSM.923549.
[157] Yang BX, Xia L, Huang R, Chen P, Luo D, Liu Q, et al. Relationship between eHealth literacy and psychological status during COVID-19 pandemic: a survey of Chinese residents. J Nurs Manag 2020:1–8. https://doi.org/10.1111/jonm.13221.
[158] Yang H, Shi R, Chi Y, Qiao Z, Wu Y, Zhu Z, et al. Knowledge, anxiety, depression, and sleep quality among medical staff in central south areas of China during the break of COVID-19: does the level of hospitals make a difference? Front Psychiatr 2021;12:714870. https://doi.org/10.3389/fpsyt.2021.714870.
[159] Yeni K, Tulek Z, Terzi M. A year with the fear of COVID-19 in multiple sclerosis patients: examination of depression, sleep quality and quality of life before and after the pandemic. Multi Scler. Relat. Disord. 2021:103370. https://doi.org/10.1016/j.msard.2021.103370.
[160] Yin Q, Sun Z, Liu T, Ni X, Deng X, Jia Y, et al. Posttraumatic stress symptoms of health care workers during the Corona virus disease 2019. Clin Psychol Psychother 2020;27:1–2. https://doi.org/10.1002/cpp.2477.
[161] Younes S, Safwan J, Rahal M, Hammoudi D, Akiki Z, Akel M. Effect of COVID-19 on mental health among the young population in Lebanon. L'encephale 2021. https://doi.org/10.1016/j.encep.2021.06.007.
[162] Youssef N, Mostafa A, Ezzat R, Yosef M, El Kassas M. Mental health status of health-care professionals working in quarantine and non-quarantine Egyptian hospitals during the COVID-19 pandemic. East Mediterr Health J 2020;20:1155–64. https://doi.org/10.26719/emhj.20.116.
[163] Yu BY-M, Yeung W-F, Lam JC-S, Yuen SC-S, Lam SC, Chung VC-H, et al. Prevalence of sleep disturbances during COVID-19 outbreak in an urban Chinese population: a cross-sectional study. Sleep Med 2020;74:18–24. https://doi.org/10.1016/j.sleep.2020.07.009.
[164] Yue L, Zhao R, Xiao Q, Zhuo Y, Yu J, Meng X. The effect of mental health on sleep quality of front-line medical staff during the COVID-19 outbreak in China: a cross-sectional study. PLoS One 2021;16:e0253753. https://doi.org/10.1371/journal.pone.0253753.
[165] Zarzour M, Hachem C, Kerbage H, Richa S, Choueifaty D, Saliba G, et al. Anxiety and sleep quality in a sample of lebanese healthcare workers during the COVID-19 outbreak. L'encephale 2021. https://doi.org/10.1016/j.encep.2021.06.016.
[166] Zhang X, Zhao K, Zhang G, Feng R, Chen J, Xu D, et al. Occupational stress and mental health: a comparison between frontline medical staff and non-frontline medical staff during the 2019 novel Coronavirus disease outbreak. Front Psychiatr 2020;11:555703. https://doi.org/10.3389/fpsyt.2020.555703.
[167] Zhang W, Wang K, Yin L, Zhao W, Xue Q, Peng M, et al. Mental health and psychosocial problems of medical health workers during the COVID-19 epidemic in China. Psychother Psychosom 2020;89:242–50. https://doi.org/10.1159/000507639.
[168] Zhang X, Zou R, Liao X, Bernardo AB, Du H, Wang Z, et al. Perceived stress, hope, and health outcomes among medical staff in China during the COVID-

19 pandemic. Front Psychiatr 2021;11:588008. https://doi.org/10.3389/fpsyt.2020.588008.
[169] Zhao X, Zhang T, Li B, Yu X, Ma Z, Cao L, et al. Job-related factors associated with changes in sleep quality among healthcare workers screening for 2019 novel Coronavirus infection: a longitudinal study. Sleep Med 2020;75:21–6. https://doi.org/10.1016/j.sleep.2020.07.027.
[170] Zheng X, Guo Y, Yang H, Luo L, Ya B, Xu H, et al. A cross-sectional study on mental health problems of medical and nonmedical students in shandong during the COVID-19 epidemic recovery period. Front Psychiatr 2021;12:680202. https://doi.org/10.3389/fpsyt.2021.680202.
[171] Zhou Y, Yang Y, Shi T, Song Y, Zhou Y, Zhang Z, et al. Prevalence and demographic correlates of poor sleep quality among frontline health professionals in Liaoning province, China during the COVID-19 outbreak. Front Psychiatr 2020;11:520. https://doi.org/10.3389/fpsyt.2020.00520.
[172] Zhou Y, Ding H, Zhang Y, Zhang B, Guo Y, Cheung T, et al. Prevalence of poor psychiatric status and sleep quality among frontline healthcare workers during and after the COVID-19 outbreak: a longitudinal study. Transl Psychiatry 2021;11:1–6. https://doi.org/10.1038/s41398-020-01190-w.
[173] Zhu W, Fang Y, Bai Z, Li N, Zhao J, Hu Z. Effect of emerging major infectious diseases on sleep quality of medical workers: findings from medical workers providing support during the COVID-19 pandemic. Med Sci Mon Int Med J Exp Clin Res 2021;27:e931881. https://doi.org/10.12659/MSM.931881.
[174] Zhuo K, Gao C, Wang X, Zhang C, Wang Z. Stress and sleep: a survey based on wearable sleep trackers among medical and nursing staff in Wuhan during the COVID-19 pandemic. General Psych 2020;33:e100260. https://doi.org/10.1136/gpsych-2020-100260.
[175] Zhuo L, Wu Q, Le H, Li H, Zheng L, Ma G, et al. COVID-19-related intolerance of uncertainty and mental health among back-to-school students in Wuhan: the moderation effect of social support. Int J Environ Res Publ Health 2021;18:981. https://doi.org/10.3390/ijerph18030981.
[176] Kowal M, Coll-Martın T, Ikizer G, Rasmussen J, Eichel K, Studzińska A, et al. Who is the most stressed during the COVID-19 pandemic? Data from 26 countries and areas. Appl Psychol: Health and Well-Being 2020;12:946–66. https://doi.org/10.1111/aphw.12234.
[177] Gardani M, Bradford DR, Russell K, Allan S, Beattie L, Ellis J, et al. A systematic review and meta-analysis of poor sleep, insomnia symptoms and stress in undergraduate students. Sleep Med Rev 2021:101565. https://doi.org/10.1016/j.smrv.2021.101565.
[178] Ballesio A, Zagaria A, Musetti A, Lenzo V, Palagini L, Quattropani MC, et al. Longitudinal associations between stress and sleep disturbances during COVID-19. Stress Health 2022. https://doi.org/10.1002/smi.3144.
[179] Diaz F, Cornelius T, Bramley S, Venner H, Shaw K, Dong M, et al. The association between sleep and psychological distress among New York City healthcare workers during the COVID-19 pandemic. J Affect Disord 2022;298:618–24. https://doi.org/10.1016/j.jad.2021.10.033.
[180] AlAteeq D, Almokitib A, Mohideen M, AlBlowi N, Fayed A, Alshahrani SM, et al. Stress, sleep, and use of sleep aids among physicians during the COVID-19 pandemic. J Nat Sci Med 2021;4:197. https://doi.org/10.4103/jnsm.jnsm_177_20.
[181] Aly HM, Nemr NA, Kishk RM, bakr Elsaid NMA. Stress, anxiety and depression among healthcare workers facing COVID-19 pandemic in Egypt: a cross-sectional online-based study. BMJ Open 2021;11:e045281. https://doi.org/10.1136/bmjopen-2020-045281.
[182] Marvaldi M, Mallet J, Dubertret C, Moro MR, Guessoum SB. Anxiety, depression, trauma-related, and sleep disorders among healthcare workers during the COVID-19 pandemic: a systematic review and meta-analysis. Neurosci Biobehav Rev 2021;126:252–64. https://doi.org/10.1016/j.neubiorev.2021.03.024.
[183] Akram U, Ypsilanti A, Gardani M, Irvine K, Allen S, Akram A, et al. Prevalence and psychiatric correlates of suicidal ideation in UK university students. J Affect Disord 2020;272:191–7. https://doi.org/10.1016/j.jad.2020.03.185.
[184] Hyun S, Hahm HC, Wong GTF, Zhang E, Liu CH. Psychological correlates of poor sleep quality among US young adults during the COVID-19 pandemic. Sleep Med 2021;78:51–6. https://doi.org/10.1016/j.sleep.2020.12.009.
[185] Scarpelli S, Alfonsi V, Gorgoni M, Musetti A, Filosa M, Quattropani MC, et al. Dreams and nightmares during the first and second wave of the COVID-19 infection: a longitudinal study. Brain Sci 2021;11:1375. https://doi.org/10.3390/brainsci11111375.
[186] Fränkl E, Scarpelli S, Nadorff MR, Bjorvatn B, Bolstad CJ, Chan NY, et al. How our dreams changed during the COVID-19 pandemic: effects and correlates of dream recall frequency-a multinational study on 19,355 adults. Nat Sci Sleep 2021;13:1573. https://doi.org/10.2147/NSS.S324142.
[187] Randler C. Gender differences in Morningness-Eveningness assessed by self-report questionnaires: a meta-analysis. Pers Indiv Differ 2007;43:1667–75. https://doi.org/10.1016/j.paid.2007.05.004.
[188] Conversano C, Di Giuseppe M, Miccoli M, Ciacchini R, Gemignani A, Orrù G. Mindfulness, age and gender as protective factors against psychological distress during COVID-19 pandemic. Front Psychol 2020. https://doi.org/10.3389/fpsyg.2020.01900. 1900.
[189] Hinz A, Glaesmer H, Brähler E, Löffler M, Engel C, Enzenbach C, et al. Sleep quality in the general population: psychometric properties of the Pittsburgh Sleep Quality Index, derived from a German community sample of 9284 people. Sleep Med 2017;30:57–63. https://doi.org/10.1016/j.sleep.2016.03.008.
[190] Ohayon MM. Epidemiological overview of sleep disorders in the general population. Sleep Med Res 2011;2:1–9.
[191] Wang C, Pan R, Wan X, Tan Y, Xu L, Ho CS, et al. Immediate psychological responses and associated factors during the initial stage of the 2019 Coronavirus disease (COVID-19) epidemic among the general population in China. Int J Environ Res Publ Health 2020;17:1729. https://doi.org/10.3390/ijerph17051729.
[192] Bergdahl J, Bergdahl M. Perceived stress in adults: prevalence and association of depression, anxiety and medication in a Swedish population. Stress Health: J Int Soc Invest Stress 2002;18:235–41. https://doi.org/10.1002/smi.946.
[193] Gao W, Ping S, Liu X. Gender differences in depression, anxiety, and stress among college students: a longitudinal study from China. J Affect Disord 2020;263:292–300. https://doi.org/10.1016/j.jad.2019.11.121.
[194] Cherepanov D, Palta M, Fryback DG, Robert SA. Gender differences in health-related quality-of-life are partly explained by sociodemographic and socioeconomic variation between adult men and women in the US: evidence from four US nationally representative data sets. Qual Life Res 2010;19:1115–24. https://doi.org/10.1007/s11136-010-9673-x.
[195] Lee KH, Xu H, Wu B. Gender differences in quality of life among community-dwelling older adults in low-and middle-income countries: results from the study on global AGEing and adult health (SAGE). BMC Publ Health 2020;20:1. https://doi.org/10.1186/s12889-020-8212-0. 0.
[196] Grandner MA, Kripke DF, Yoon I-Y, Youngstedt SD. Criterion validity of the Pittsburgh sleep quality index: investigation in a non-clinical sample. Sleep Biol Rhythm 2006;4:129–36. https://doi.org/10.1111/j.1479-8425.2006.00207.x.
[197] He L, Zhao W, Gao Y, Gao X, Lei X. The effect of COVID-19 lockdowns on sleep time perception: comparing actigraphy and sleep diary measures. Int J Psychophysiol 2021;167:86–93. https://doi.org/10.1016/j.ijpsycho.2021.07.001.
[198] Wang H, He L, Gao Y, Gao X, Lei X. Effects of physical activity and sleep quality on well-being: a wrist actigraphy study during the pandemic. Appl Psychol: Health and Well-Being 2021;13:394–405. https://doi.org/10.1111/aphw.12255.
[199] Conte F, De Rosa O, Rescott ML, Arabia TP, D'Onofrio P, Lustro A, et al. High sleep fragmentation parallels poor subjective sleep quality during the third wave of the COVID-19 pandemic: an actigraphic study. J Sleep Res 2021:e13519. https://doi.org/10.1111/jsr.13519.
[200] Pilcher JJ, Dorsey LL, Galloway SM, Erikson DN. Social isolation and sleep: manifestation during COVID-19 quarantines. Front Psychol 2022:6476. https://doi.org/10.3389/fpsyg.2021.810763.
[201] Beck AT. Cognitive therapy of depression. Guilford press; 1979.
[202] Means MK, Edinger JD, Glenn DM, Fins AI. Accuracy of sleep perceptions among insomnia sufferers and normal sleepers. Sleep Med 2003;4:285–96. https://doi.org/10.1016/s1389-9457(03)00057-1.
[203] Fernandez-Mendoza J, Calhoun SL, Bixler EO, Karataraki M, Liao D, Vela-Bueno A, et al. Sleep misperception and chronic insomnia in the general population: the role of objective sleep duration and psychological profiles. Psychosom Med 2011;73:88. https://doi.org/10.1097/PSY.0b013e3181fe365a.
[204] Korman M, Tkachev V, Reis C, Komada Y, Kitamura S, Gubin D, et al. COVID-19-mandated social restrictions unveil the impact of social time pressure on sleep and body clock. Sci Rep 2020;10:1. https://doi.org/10.1038/s41598-020-79299-7.
[205] Conte F, Rescott ML, De Rosa O, Cellini N, Coppola A, Cerasuolo M, et al. Changes in dream features across the first and second waves of the COVID-19 pandemic. Jo. Sleep Res. 2022;31:e13425. https://doi.org/10.1111/jsr.13425.
[206] Lenzo V, Sardella A, Musetti A, Freda MF, Lemmo D, Vegni E, et al. The relationship between resilience and sleep quality during the second wave of the COVID-19 pandemic: a longitudinal study. Nat Sci Sleep 2022;14:41. https://doi.org/10.2147/NSS.S344042.
[207] Kimhi S, Marciano H, Eshel Y, Adini B. Resilience and demographic characteristics predicting distress during the COVID-19 crisis. Soc Sci Med 2020;265:113389. https://doi.org/10.1016/j.socscimed.2020.113389.
[208] Ahmed O, Hossain KN, Siddique RF, Jobe MC. COVID-19 fear, stress, sleep quality and coping activities during lockdown, and personality traits: a person-centered approach analysis. Pers Indiv Differ 2021;178:110873. https://doi.org/10.1016/j.paid.2021.110873.
[209] Kocevska D, Blanken TF, Van Someren EJ, Rösler L. Sleep quality during the COVID-19 pandemic: not one size fits all. Sleep Med 2020;76:86–8. https://doi.org/10.1016/j.sleep.2020.09.029.
[210] Higgins J. Cochrane handbook for systematic reviews of interventions. The Cochrane Collaboration; 2011 [updated march 2011], Version 5.1. 0.
[211] Buysse DJ, Thompson W, Scott J, Franzen PL, Germain A, Hall M, et al. Daytime symptoms in primary insomnia: a prospective analysis using ecological momentary assessment. Sleep Med 2007;8:198–208. https://doi.org/10.1016/j.sleep.2006.10.006.