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RESEARCH ARTICLE

Sleep disorders during the COVID-19 pandemic: Results from the second phase of web-based EPICOVID19 study

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Abstract

The COVID-19 pandemic has induced significant impairments, including sleep disturbances. The present study aimed to explore the impact of fear in relation to stress on sleep disorders among Italian adults and older participants in the second phase of the EPICOVID19 web-based survey (January-February 2021). Sleep disturbances during the pandemic were evaluated using the Jenkins Sleep Scale, perceived stress through the 10-item Perceived Stress Scale and fear of contagion and about economic and job situation with four ad hoc items. The strength of the pathways between stress, sleep disturbances and fear was explored using structural equation modelling, hypothesising that stress was related to sleep disturbances and that fear was associated with both stress and sleep problems. Out of 41,473 participants (74.7% women; mean age 49.7 ± 13.1 years), 8.1% reported sleep disturbances and were more frequently women, employed in a work category at risk of infection or unemployed, and showed higher deprivation scores. Considering an a priori hypotheses model defining sleep and stress scores as endogenous variables and fear as an exogenous variable, we found that fear was associated with sleep problems and stress, and stress was associated with sleep problems; almost half of the total impact of fear on sleep quality was mediated by stress. The impact of stress on sleep quality was more evident in the younger age group, among individuals with a lower socioeconomic status and healthcare workers. Fear related to COVID-19 seem to be associated with sleep disturbances directly and indirectly through stress.

KEYWORDS
EPICOVID19 survey, fear, sleep disturbances, stress

Collaborators of the EPICOVID19 Working Group are indicated in the Acknowledgement section.

Caterina Trevisan, Antonio De Vincentis contributed equally to this work.

1 | INTRODUCTION

The global COVID-19 pandemic has induced serious and significant impairments in several aspects of daily living in adult and older people. Sleep pattern and quality alterations have also been observed in a variable proportion of individuals ranging from 13% to 38% in the general population (Bacaro et al., 2020; Kokou-Kpolou et al., 2020; Zhou et al., 2020). Sleep derangements included a broad spectrum of problems such as insomnia, disrupted sleep continuity, changes in the sleep-wake cycle, or non-restorative sleep (AlRasheed et al., 2022; Jahrami et al., 2021), and were more frequent in young subjects, women, living in urban areas and with poor social support (Bhat & Chokroverty, 2022). Pre-existing mental illness, in particular depression and anxiety, was another commonly observed feature (Bhat & Chokroverty, 2022).

Many factors could be responsible for this increased rate of sleep impairments during the COVID-19 pandemic. First of all, the observed increase of psychological distress, anxiety, post-traumatic stress disorders, and stress in the general population could have certainly contributed (Xiong et al., 2020), since these are all well-known factors that can influence sleep hygiene (Cutler, 2016; Oh et al., 2019). Then, social isolation resulting from lockdowns and quarantines was also associated with sleep disturbances. Noteworthy, sleep disorders were more frequently observed among healthcare providers and workers in high-risk environments for SARS-CoV2 infection (Stewart et al., 2021; Zhan et al., 2020), and their occurrence was also reported in the absence of active SARS-CoV-2 infection, thus suggesting the importance of social and psychological elements related to the pandemic.

In this scenario, fear of COVID-19, including the fear of contagion for oneself and family members (Cori et al., 2021) or undergoing the economic consequences of the pandemic, may have played a central role in explaining the increase of sleep disturbances during the COVID-19 pandemic. Indeed, fear is the most primitive feeling in response to a real or perceived threat. Excessive fear levels may lead to stress and panic, that -if prolonged in time-can impair several psychophysical aspect of life. It has been described that COVID-19 fear was strongly associated with sleep disturbances, and that this association was mediated by perceived stress (Siddique et al., 2021). However, the strength of the relation pathways between these factors has not been specifically investigated. Moreover, little is known about possible differences in the interplay of such relationships in different groups of individuals, such as the younger and older population, which have likely coped in distinct ways with the pandemic (Bhat & Chokroverty, 2022).

The primary aim of the study was to evaluate the association between fear of COVID-19 and sleep disorders, and the possible mediation of stress in this relationship. As secondary aims, we wanted to describe the individuals mostly affected by sleep problems during a challenging situation like the COVID-19 pandemic and the factors linked to a stronger mediating effect of stress in the relationship between fear of COVID-19 and sleep disorders. We hypothesised that stress mediated at least in part the relationship between fear and sleep disturbances during the COVID-19 pandemic, and that some sociodemographic and health-related factors, such as age, sex, socioeconomic level, and worse health status, might influence that interplay.

2 | MATERIALS AND METHODS

2.1 | Study design and setting

EPICOVID19 is a web-based survey conducted in Italy in April-June 2020 (first phase (Adorni et al., 2020)) and then in January-February 2021 (Adorni et al., 2022). In brief, a self-selected sample of adult volunteers living in Italy, recruited via mailing lists, social media platforms, press releases, television and radio news programs, word of mouth, and the study website (https://epicovid19.itb.cnr.it/) was asked to complete a questionnaire implemented through the European Commission's open-source EUSurvey (https://ec.europa.eu/eusurvey). The inclusion criteria were age ≥18 years; having access to a mobile phone, computer, or tablet with Internet connectivity; and providing online consent to participate in the study.

Out of the 198,822 participants who completed the questionnaire for the first phase of the survey, 41,473 participants completed the second phase in January—February 2021 and were included in the present analysis (Adorni et al., 2022).

The Ethics Committee of the Istituto Nazionale per le Malattie Infettive IRCCS Lazzaro Spallanzani approved the EPICOVID19 study protocols (first phase No. 70, 12/4/2020; second phase No. 249, 14/1/2021). Participants were informed about the study when they accessed the online platform and were asked to fill in an informed consent form. Participation in the survey was voluntary, and no compensation was given to respondents. The study was carried out in accordance with the principles of the Declaration of Helsinki. All data were handled and stored following the European Union General Data Protection Regulation 2016/679, and data transfer included encrypting/decrypting and password protection.

The study design and data were registered in ClinicalTrials.gov, NCT04471701.

2.2 | Data collection and variables

The variables were collected with a self-administered questionnaire. Sleep problems were evaluated using the Jenkins Sleep Scale (JSS) (Jenkins et al., 1988). Four items (difficulty falling asleep, waking up at night, difficulty staying asleep and waking up exhausted in the morning instead of sleeping as usual) were evaluated with reference to the previous month, and each item, based on the frequency of these disturbances, was rated on a Likert scale from 0 (never) to 5 (22–30 days). The scale allows scoring from 0 to 20, and a cut-off ≥12 was suggested to identify a high frequency of sleep disturbance (Monterrosa-Castro et al., 2016).

The 10-item Perceived Stress Scale (PSS-10) was considered to evaluate perceived stress and feelings (Cohen, 1988). The questions were referred to the previous month, and each item was rated on a Likert-like scale from 0 to 4. The total PSS score was obtained by reversing the four positive items (0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0) and then summing all 10 items. The total score ranged from 0 to 40, with higher scores indicating higher perceived stress; scores ranging from 0 to 13 indicated low stress, 14–26 moderate stress, and 27–40 high stress.

Fear was evaluated considering four items (fear of contagion for oneself or relatives, fear about personal economic and job situation, and fear about the relatives' economic and job status) developed ad hoc for the present survey. Each item was rated on a Likert-like scale from 1 (no fear) to 5 (a lot), and the total sum score ranged from 4 to 20, with higher scores indicating a higher level of fear (Cori et al., 2021).

Jenkins Sleep Scale, PSS-10 scales and fear based on four items were evaluated for the first time in the second phase of the EPICOVID19 survey.

Other variables collected with the questionnaire and considered in the present analyses included age, sex, education, employment status since June 2020, working in a category at risk for the infection, geographical area of residence, and body mass index (BMI) (calculated as weight divided by height squared, and further categorised as healthy weight (18.5–24.9 kg/m^2), underweight (<18.5 kg/m^2), overweight (25–29.9 kg/m^2) and obesity (≥30 kg/m^2)). The number of morbidities was defined considering self-reported lung diseases, heart diseases, hypertension, renal diseases, diseases of the immune system, oncological diseases, metabolic diseases, neurological diseases, cerebrovascular diseases, liver diseases (hepatitis C, B and other disorders), depression and/or anxiety, eating disorders, and anaemia. Taking into account the number of self-reported chronic conditions listed above, participants were categorised as having none, 1, 2, 3+ morbidities. Smoking habits, frequency of alcohol beverages, physical activity before the pandemic, self-perceived health status, self-reported dependency in daily activities, having had quarantine or fiduciary isolation periods, and reporting positive nasopharyngeal swab (NPS) or serological test (ST) for COVID-19 during the study period were also considered in the analyses. Townsend Deprivation Scores were used as a proxy for deprivation (Mackenbach, 1988). For each participant, four dichotomised variables were considered: unemployment, non-ownership of the house where he/she lives, no car owned by family members, and house crowding (defined as a number of cohabitants greater than the number of rooms in the house, kitchen and bathrooms excluded). The total score ranged from 0 to 4, with a higher score indicating higher deprivation.

2.3 | Statistical analyses

The categorical variables were presented as counts and percentages; the continuous variables were summarised using means and standard deviations (SD). Descriptive statistics evaluated the main characteristics of individuals with sleep disturbance defined according to JSS, with respect to those without sleep disturbance.

Multivariable logistic regression models were defined to evaluate participants' characteristics associated with sleep disturbance, considering among independent variables age, sex, education, employment status and working in a category at risk for the infection, geographical area of residence, deprivation score, smoking status, frequency of alcohol beverages between meals, self-perceived health status, stress levels, BMI, number of morbidities, self-reported depression or anxiety, self-reported dependency in daily activities, physical activity practice before the pandemic, quarantine or fiduciary isolation periods, being positive for COVID-19 during the study period and fear about COVID-19 pandemic. Independent variables were selected based on the scientific evidence supporting their relationship with the study outcomes, and after considering the results at the univariate analysis (using a p-value <0.05 as a cut-off) and the possible collinearity between different factors. The linearity assumption for continuous variable age was evaluated considering the analysis of quartiles through the following steps: the quartiles of the distribution of age were identified, and a multivariable model replacing age with the categorical variable defined based on quartiles (four level, with the lowest as the reference) was defined; the three estimates versus the midpoint of the three quartiles were plotted and the linearity was graphically evaluated (Hosmer & Lemeshow, 2000). Adjusted Odds ratios (aORs) were presented with the corresponding 95% confidence intervals.

The strength of the pathways between perceived stress, sleep disturbances during the pandemic and fear was explored using structural equation modelling (SEM), hypothesising that stress levels were related to sleep disturbances and that fear was associated with both stress and sleep problems (McCarthy et al., 2022; Morin et al., 2022). The whole dataset (i.e. participants with or without sleep disorders) was included in the analysis. The adequacy of the model fit was evaluated considering the chi-square test, standardized root means square residual (SRMR) and goodness-of-fit index (GFI).

Analyses were repeated after stratifying the population by age (using a cut-off of 65 years, according to the current literature (Orimo et al., 2006; WHO, 2022) and sex (multi-group analysis), in light of the possible influence of these factors on the individual burden of the pandemic and the well-known quantitative and qualitative differences of sleep disorders by age and sex (Dorsey et al., 2020; Maggi et al., 1998; Soldatos et al., 2005). As sensitivity analyses, we assessed our findings among participants having an occupation at risk for the infection, health staff, students, and considering deprivation scores and having been positive for COVID-19 or hospitalised for COVID-19 during the study period.

Two-tail p-values <0.05 were considered statistically significant. The analyses were performed using SAS statistical package, version 9.4 (SAS Institute Inc., Cary, NC, USA).

3 | RESULTS

3.1 | General characteristics of individuals with sleep disturbances

Data from the second phase of the EPICOVID19 survey were considered in the analyses, with the only exception of physical activity practice before the pandemic that was obtained from the first questionnaire. Out of the total 41,473 participants in the second phase of the EPICOVID19 survey (74.7% women; mean age 49.7 ± 13.1 years), 3359 (8.1%; 8.5% in those <65 years, and 6.1% in those aged 65+) reported sleep disturbances. Among 3359 subjects with sleep disturbances, nearly half (45.8%) had trouble falling asleep almost every day, 30.4% often woke up without trouble falling asleep again, while 43.9% had trouble falling asleep after waking up during the night. Around 41% of the subjects complained of waking up exhausted (Table S1). A similar burden of trouble falling asleep was observed in older individuals, whereas significantly more severe alterations were found for waking up during the night with/out difficulty falling asleep again (Table S1).

Table 1 reports the main characteristics of the study population according to the presence of sleep disturbances. Higher percentages of women (74.7% vs. 59.4%), individuals employed in a work category at risk of infection (26% vs. 21%) or unemployed (8.4% vs. 4.9%), and subjects with deprivation score≥3 (1.4% vs. 0.5%) were found among respondents with sleep disturbances compared to those with no sleep disturbances. Respondents with sleep disturbances showed more fear about the COVID-19 pandemic and obtained higher stress levels; they also reported a lower frequency of alcohol consumption and physical activity before the pandemic, more comorbidities and mood alterations (depression/anxiety), poorer self-perceived health and functional status.

Consistent findings were observed in the subgroup of individuals aged 65 years or more, or less than 65 years (Table S2, S3).

3.2 | Factors associated with sleep disturbances

Moderate/high stress levels (aOR 2.85) or fear about the COVID-19 pandemic (aOR 1.10), female sex (aOR 1.55), being employed at risk of infection or unemployed (aOR 1.29 or 1.20), having bad self-perceived health status (aOR 2.89), having more comorbidities (aOR for 3 + 1.68), depression/anxiety (aOR 1.94), and having gotten COVID-19 during the study period (aOR 1.35) showed significant positive associations with sleep disturbance, while a negative association emerged for living in Central regions of Italy (aOR 0.89 vs. Northern ones) (Table 2).

Both for younger subjects and respondents aged 65 or older, sleep disturbances were significantly and positively associated with female sex (OR of 1.80 and 1.51, respectively), bad self-perceived health status (OR 3.79 and 2.74), depression/anxiety (OR 1.55 and 2.00) and occurrence of COVID-19 during the study period (OR 1.15 and 1.37) with regard to increased sleep disturbances.

3.3 | Relation between sleep disturbance, stress and fear

Most of the respondents with sleep disturbances (~80%) also reported moderate/high stress levels (Table 1; Figure 1). These individuals showed higher fear of the COVID-19 pandemic (mean fear levels 10.4, SD 3.5, vs. 8.7, SD 3.6). Subjects with sleep disturbances but without moderate/high stress (~20%) were more likely to be men (47.7% vs. 30.7%), not to be employed in a work category at risk of infection (32.6% vs. 44.5%), and to be free from comorbidities (65.5% vs. 51.7%) (data not shown).

Significant correlations were found between perceived stress score and sleep problems (Spearman rho = 0.39, $p < 0.0001$), between fear score and perceived stress score (Spearman rho = 0.32, $p < 0.0001$), and between fear score and sleep problems score (Spearman rho = 0.22, $p < 0.0001$). Considering an a priori hypotheses model defining sleep problems and perceived stress scores as endogenous variables and fear scores as an exogenous variable, after adjusting for potential confounders, we found that fear was associated with sleep problems (beta = 0.11 based on standardized estimates, $p < 0.0001$) and with stress (beta = 0.27, $p < 0.0001$), and that stress was also associated with sleep problems (beta = 0.37, $p < 0.0001$) (Figure 2).

This suggests that fear related to the COVID-19 pandemic is associated with sleep problems both directly and indirectly through stress. The indirect effect of fear on sleep problems was almost equal to the direct effect (0.10 and 0.11, respectively, $p < 0.0001$), suggesting that almost half of the total impact of fear on sleep quality was mediated by stress. Both direct and indirect effects were significant and indicated small to medium effects. In relation to the goodness-of-fit of the model, chi-square value was close to zero, GFI = 1 (values range from 0 to 1, ideal value > 0.90), and SRMR = 0 (ideal value < 0.05).

The results of the sensitivity analyses (Supplementary Figure S1) in different subgroups of the study population showed that the proportion of the total effect that is mediated by stress ranged from 0.45 to 0.55. In particular, the impact of perceived stress on sleep quality was more marked in the younger age group and healthcare workers, while no substantial differences were found between men and women or among those who got COVID-19. Instead, individuals with a lower socioeconomic status were characterised by a stronger indirect pathway from COVID-19-related fear to worse sleep quality through higher perceived stress.

4 | DISCUSSION

Our survey shows that fear related to COVID-19 was associated with the presence of sleep disturbances directly and indirectly through the development of stress. The role of stress on sleep disorders was stronger among younger people, healthcare professionals, and individuals with lower socioeconomic levels. Concerning age, a different pattern of factors were associated with sleep disorders in

TABLE 1 Characteristics of the participants in the *second phase* of the EPICOVID19 survey by sleep disturbance[a] (univariable analysis).

	Sleep disturbance (n = 3359)	No sleep disturbance (n = 38,114)	OR	95% CI
Sex, female, *n* (%)	2509 (74.7)	22,637 (59.4)	2.02	1.86–2.19
Age, years, mean ± SD	49.7 ± 13.1	50.8 ± 13.6	0.99	0.98–0.99
Education, *n* (%)				
Elementary school or less, or middle school	147 (4.4)	1234 (3.2)	1.00	
High school or University degree or post-graduate	3212 (95.6)	36,880 (96.8)	0.73	0.61–0.87
Employment status since 01.06.2020, *n* (%)				
Employed, work category not at risk for the infection	1314 (39.1)	17,259 (45.3)	1.00	
Employed, work category at risk for the infection	874 (26.0)	8140 (21.3)	1.41	1.29–1.54
Temporary layoff	60 (1.8)	433 (1.1)	1.82	1.38–2.40
Unemployed	282 (8.4)	1871 (4.9)	1.98	1.73–2.27
Student	151 (4.5)	1282 (3.4)	1.55	1.30–1.85
Retired, other	678 (20.2)	9129 (24.0)	0.98	0.89–1.07
Italian area of residence[b], *n* (%)				
Northern regions	2329 (69.4)	26,715 (70.2)	1.00	
Central regions	641 (19.1)	7696 (20.2)	0.96	0.87–1.05
South or insular regions	386 (11.5)	3670 (9.6)	1.21	1.08–1.35
Deprivation score, *n* (%)				
0	1867 (55.6)	23,506 (61.7)	1.00	
1	1160 (34.5)	12,083 (31.7)	1.21	1.12–1.31
2	285 (8.5)	2312 (6.1)	1.55	1.36–1.77
3, 4	47 (1.4)	213 (0.5)	2.78	2.02–3.83
Frequency of alcohol beverages, *n* (%)				
Never	746 (22.2)	7036 (18.4)	1.00	
≤ Once a week	1457 (43.4)	16,715 (43.9)	0.82	0.75–0.90
2–3 times a week	556 (16.5)	7021 (18.4)	0.75	0.67–0.84
4 or more times a week	600 (17.9)	7342 (19.3)	0.77	0.69–0.86
Physical activity before the pandemic, *n* (%)				
No or less than 10 min/week	888 (26.4)	8070 (21.1)	1.00	
10–150 min/week	1406 (41.9)	16,906 (44.4)	0.76	0.69–0.83
More than 150 min/week	1065 (31.7)	13,138 (34.5)	0.74	0.67–0.81
Self-perceived health status, *n* (%)				
Bad or very bad	181 (5.4)	458 (1.2)	1.00	
Adequate	1255 (37.4)	6949 (18.2)	0.46	0.38–0.55
Good or very good	1923 (57.2)	30,707 (80.6)	0.16	0.13–0.19
Number of morbidities, *n* (%)				
0	1536 (45.7)	24,493 (64.2)	1.00	
1	918 (27.3)	8677 (22.8)	1.69	1.55–1.84
2	506 (15.1)	3299 (8.7)	3.87	3.43–4.37
3+	399 (11.9)	1645 (4.3)	2.45	2.20–2.72

(Continues)

TABLE 1 (Continued)

	Sleep disturbance (n = 3359)	No sleep disturbance (n = 38,114)	OR	95% CI
Depression or anxiety, *n* (%)	828 (24.7)	3238 (8.5)	3.52	3.23–3.84
Dependency in daily activities, *n* (%)	260 (7.7)	1650 (4.3)	1.85	1.62–2.12
Stress level according to PSS-10 scale, *n* (%)				
Low stress (0–13)	602 (19.8)	17,582 (51.9)	1.00	
Moderate stress (14–26)	1926 (63.5)	15,307 (45.2)	3.68	3.35–4.04
High stress (27–40)	505 (16.7)	968 (2.9)	15.2	13.3–17.4
Fear about COVID-19 pandemic, mean ± SD	10.1 ± 3.6	8.2 ± 3.5	1.17	1.16–1.18
COVID-19[c] during study period, *n* (%)	491 (39.6)	3920 (32.7)	1.35	1.20–1.52
Quarantine or fiduciary isolation periods, *n* (%)	1199 (35.7)	10,999 (28.9)	1.37	1.27–1.47

Abbreviations: CI, Confidence Interval; OR, Odds Ratio; SD, Standard Deviation.

[a]JSS score ≥12.

[b]Based on data from the first survey.

[c]Defined as those who reported at least one positive result at the NPS or a ST during the considered study period.

adults versus older individuals, especially sociodemographic, medical, and lifestyle characteristics. Irrespective of age, however, individuals reporting sleep disturbances during the COVID-19 pandemic were more likely to have mild to moderate stress levels.

The associations of fear related to COVID-19 and stress with sleep problems have already emerged in previous studies involving young or older individuals (Ahmed et al., 2021; De Los Santos et al., 2022; Grossman et al., 2021; Şimşir et al., 2022). However, despite some contrasting data on the relationship between fear and sleep quality (Ahammed et al., 2021), the negative influence of fear related to COVID-19 on stress levels has been consolidated by a recent meta-analysis that found a moderate direct association not modified by sociodemographic factors (Erbiçer et al., 2021). In light of this evidence and under the hypothesis of an interplay between fear and stress affecting sleep quality, we took a step forward by disentangling their effects. Our results suggest that fear related to COVID-19 is associated with sleep quality both directly and indirectly through stress development. These findings align with a previous study involving a smaller cohort of Bangladeshi adults, which found similar results, especially in men (Siddique et al., 2021). However, that interesting work assessed only subjective sleep quality and, compared with evaluations considering both frequency and intensity of sleep disturbances, could therefore be affected by a higher risk of misclassification bias. In our sample, we did not observe any substantial difference in the interplay between fear and stress by sex or history of COVID-19. Instead, looking at different subgroups of participants, we found that stress variably mediated from 45% to 55% of the total effect of fear on sleep problems. In particular, the impact of perceived stress on sleep quality was more marked in the younger ones and healthcare workers, and a stronger indirect pathway of fear-stress-sleep disorders emerged for those with a lower socioeconomic status. These findings offer interesting insights on the categories for which appropriate interventions should be addressed to break this detrimental chain of effects.

The mechanisms through which fear may be associated with health-related outcomes, including stress and sleep problems, are several and involve the activation of neurocircuitry processes that interact with those controlling stress response (Shin & Liberzon, 2010). Moreover, by triggering the stress axis, fear can establish an inflammatory status, which seems to be associated with poor sleep quality with a bidirectional association still not fully clarified (Dolsen et al., 2019). Previous studies underlined that sleep problems are related with an increase in serum cytokines, such as interleukine-6 and C-reactive protein (Irwin et al., 2016; Opp, 2009), and this effect may be mediated by the presence of low positive affect (Zagaria et al., 2022). Regarding the association between fear related to COVID-19 and chronic diseases, it is interesting to point out that in our previous study on the first EPICOVID-19 questionnaire, fear was higher when it was associated with several diseases and symptoms including depression and anxiety (Cori et al., 2021). Overall, although the original usefulness of fear was to alert individuals in front of potential danger, when this reaction is excessive and not linked to real risky situations, it may be dysfunctional and lead to more detrimental than beneficial consequences, as observed in respect of some conditions (Trevisan et al., 2020). Epidemiological data corroborate this effect since fear about COVID-19 has been demonstrated to exacerbate the association between loneliness and sleep disorders, in contrast to resilience (Grossman et al., 2021). Moreover, fear mediated the relationships between self-rated health status and insomnia, mental health and preventing behaviours related to COVID-19 (Ahorsu et al., 2020), as well as between problematic use of social media and insomnia (Ahorsu et al., 2020).

Of note, the prevalence of sleep disturbances in our sample was 8%, which is lower than that found in previous studies (Alimoradi et al., 2021; Jahrami et al., 2022), estimated at around 40%. This issue

TABLE 2 Characteristics of the participants in the *second phase* of the EPICOVID19 survey associated with sleep disturbance[a] in the overall population, and stratified by age classes (<65 vs. ≥65years) (multivariable analysis).

	All			<65 years			≥65 years		
	aOR	95% CI	*p*-value	aOR	95% CI	*p*-value	aOR	95% CI	*p*-value
Sex, female versus male	1.55	1.41–1.70	<0.0001	1.51	1.37–1.67	<0.0001	1.80	1.41–2.30	<0.0001
Age, years (5 years increase)	1.00	0.98–1.02	0.6782	1.01	0.99–1.04	0.3052	1.14	1.00–1.29	0.0443
Education, University degree/Post-graduate/High school versus middle school/Elementary school or less	0.94	0.77–1.16	0.5709	0.92	0.72–1.16	0.4641	1.08	0.70–1.68	0.7220
Employment status, versus employed not at risk for the infection			<0.0001			<0.0001			0.6389
Employed, at risk for the infection	1.29	1.16–1.42	<0.0001	1.30	1.17–1.44	<0.0001	1.08	0.59–1.95	0.8079
Temporary layoff	1.14	0.83–1.57	0.4233	1.14	0.82–1.58	0.4456	1.18	0.22–6.53	0.8467
Unemployed	1.20	1.01–1.43	0.0391	1.19	0.99–1.43	0.0606	1.17	0.60–2.30	0.6368
Student	1.23	1.00–1.52	0.0545	1.27	1.02–1.57	0.0335	--	--	--
Retired, other	0.93	0.83–1.05	0.2606	1.01	0.87–1.16	0.9126	0.84	0.56–1.27	0.4094
Italian area of residence, versus Northern regions			0.0143			0.0075			0.3931
Central regions	0.89	0.81–0.99	0.0305	0.89	0.80–1.00	0.0421	0.88	0.67–1.17	0.3831
South or insular regions	1.11	0.97–1.26	0.1265	1.15	1.00–1.31	0.0502	0.77	0.50–1.19	0.2410
Deprivation score, versus 0			0.4569			0.4987			0.7621
1	1.02	0.93–1.12	0.6514	1.02	0.93–1.12	0.7116	1.02	0.77–1.36	0.8868
2	1.06	0.90–1.25	0.5083	1.06	0.90–1.26	0.4824	0.82	0.39–1.70	0.5887
3, 4	1.37	0.93–2.01	0.1143	1.35	0.91–2.01	0.1360	2.47	0.31–19.7	0.3945
Frequency of alcohol beverages between meals, versus never			0.1309			0.1006			0.7631
≤ Once a week	0.91	0.83–1.02	0.1053	0.93	0.83–1.04	0.2102	0.90	0.68–1.20	0.4713
2–3 times a week	0.92	0.81–1.05	0.2147	0.94	0.82–1.08	0.3555	0.88	0.60–1.29	0.5140
4 or more times a week	1.03	0.90–1.17	0.6815	1.07	0.93–1.24	0.3207	0.85	0.63–1.16	0.3030
Physical activity before the pandemic, versus no or <10 min/week			<0.0001			<0.0001			0.2311
10–150 min/week	0.91	0.82–0.99	0.0472	0.91	0.82–1.01	0.0850	0.81	0.60–1.10	0.1784
More than 150 min/week	1.11	1.00–1.24	0.0464	1.13	1.01–1.27	0.0310	0.98	0.72–1.34	0.9008
Self-perceived health status, versus good/very good			<0.0001			<0.0001			<0.0001
Bad or very bad	2.89	2.35–3.57	<0.0001	2.74	2.18–3.45	<0.0001	3.79	2.25–6.37	<0.0001
Adequate	1.92	1.76–2.11	<0.0001	1.95	1.77–2.15	<0.0001	1.78	1.39–2.27	<0.0001
Number of morbidities, versus 0			<0.0001			<0.0001			0.1531
1	1.28	1.17–1.41	<0.0001	1.32	1.19–1.46	<0.0001	1.00	0.75–1.33	0.9874
2	1.44	1.26–1.63	<0.0001	1.44	1.26–1.66	<0.0001	1.29	0.94–1.76	0.1157
3+	1.68	1.45–1.96	<0.0001	1.76	1.49–2.09	<0.0001	1.39	0.97–1.99	0.0701
Depression or anxiety	1.94	1.75–2.15	<0.0001	2.00	1.79–2.24	<0.0001	1.55	1.17–2.04	0.0020
Dependency in daily activities	1.20	1.03–1.40	0.0207	1.23	1.05–1.45	0.0125	0.97	0.60–1.57	0.9123

(Continues)

TABLE 2 (Continued)

	All			<65 years			≥65 years		
	aOR	95% CI	*p*-value	aOR	95% CI	*p*-value	aOR	95% CI	*p*-value
Fear about COVID-19 pandemic (1 point increase)	1.10	1.09–1.11	<0.0001	1.10	1.09–1.12	<0.0001	1.06	1.02–1.09	0.0007
Moderate/high stress levels[b]	2.85	2.58–3.15	<0.0001	2.92	2.62–3.26	<0.0001	2.64	2.08–3.35	<0.0001
COVID-19[c] during study period, versus negative results			<0.0001			<0.0001			0.3846
At least one positive result	1.35	1.17.1.55	<0.0001	1.37	1.18–1.59	<0.0001	1.15	0.69–1.92	0.6042
No NPS or ST performed	0.92	0.84–1.02	0.1203	0.93	0.84–1.03	0.1762	0.87	0.62–1.22	0.4024
Quarantine or fiduciary isolation periods	1.07	0.97–1.17	0.1749	1.06	0.96–1.17	0.2662	1.13	0.82–1.56	0.4600

Abbreviations: CI, Confidence Interval; OR, Odds Ratio.

[a]JSS score ≥12.

[b]PSS-10 score ≥14.

[c]At least one positive result at the NPS or a ST during the considered study period.

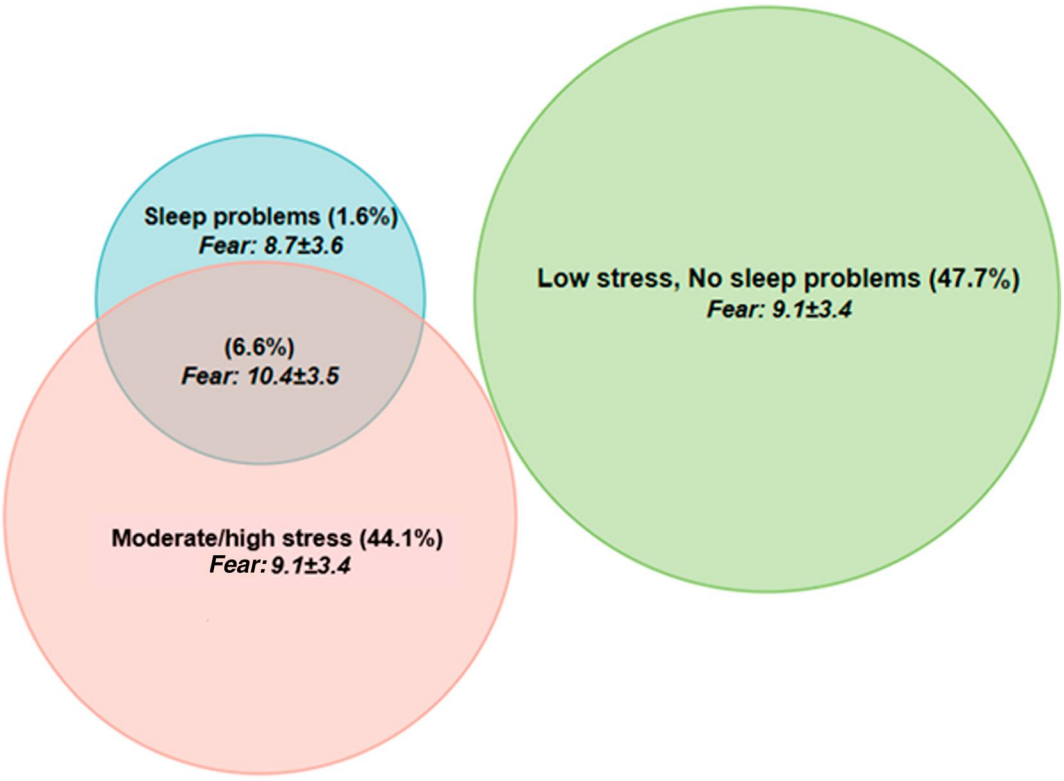
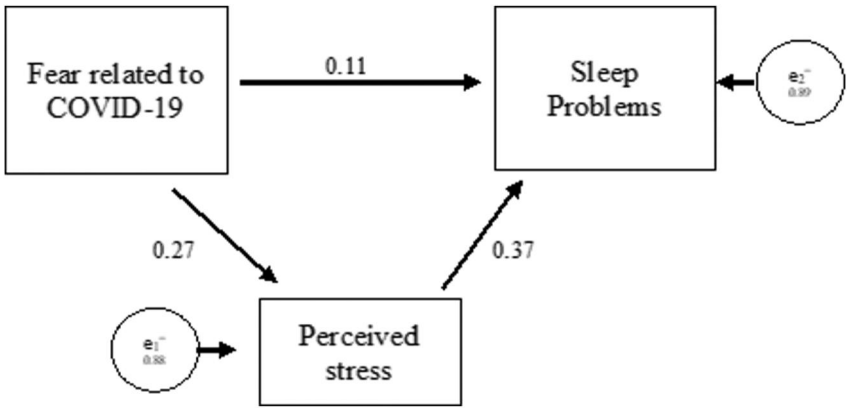


FIGURE 1 Euler diagram for sleep disturbances and stress levels for the participants in the *second phase* of the EPICOVID19 survey, and corresponding mean fear score.

is likely due to differences in the assessment methods and populations involved. A review and meta-analysis showed that the prevalence of sleep disorders was lower in Italy compared to other countries (27.3%) and varied based on the scale used (Jahrami et al., 2022). Our sample included young and old individuals participating in an Italian web-based survey, which are representative of the part of the population relatively healthy and with a rather high technological level. Furthermore, sleep disorders were assessed through the JSS evaluating the frequency of sleep problems, differently from other tools, such as the Athens Insomnia Scale or the Insomnia Severity Index, which assess the perceived severity of sleep disturbances and their self-rated impact on daily life, possibly leading to greater prevalence (Morin et al., 2011; Soldatos et al., 2000). Considering that our study had as primary aim to comprehensively

FIGURE 2 Final structural equation model.



explore the impact of the pandemic on the individuals' health and included a sleep quality scale in the second survey phase only, we believe that it can be ruled out a possible issue concerning a selection bias of individuals more sensitive to this topic because of presenting sleep disturbances (determining higher disorders' frequencies that investigations specifically focusing on sleep quality could be prone to).

Among those with a high frequency of sleep disorders, almost half reported trouble falling asleep or had frequent nocturnal awakenings with difficulties falling back asleep for most of the last month, especially women and the older ones. In keeping with previous epidemiological data, the women' higher prevalence of sleep disorders may be explained in part by the influence of oestrogen, progesterone and ovarian hormones on sleep architecture and sleep/wake rhythm, in part by the greater frequency of some chronic conditions hurting sleep quality and psychological well-being (Dorsey et al., 2020; Maggi et al., 1998). In addition, previous studies showed that the burden of the pandemic restrictions on people well-being presented substantial gender differences. For instance, women were more involved in house or family chores than men and declared to be less happy (Giurge et al., 2021). Overall, this greater burden and the related psychological discomfort, together with the higher vulnerability of women to time stress compared to men (Whillans et al., 2021), could have made them more likely to present sleep difficulties. These sex and gender-related differences tend to exacerbate with ageing, a well-recognized factor that, per se, increases the prevalence of sleep disorders. As in our cohort, previous studies found that older people are more likely to present insomnia, delayed falling asleep, and night and earlier awakenings (Soldatos et al., 2005). Furthermore, in a specific work, older people reported a greater reduction in daily functioning capacity than younger individuals but less sleepiness during the daytime (Soldatos et al., 2000). The latter issue is partially in line with our findings since those younger than 65 were more likely to wake up exhausted for most month days than the older ones.

According to the current literature, we also found that poorer self-rated health (Geiger et al., 2012; Silva-Costa et al., 2015) and mood disorders (Ji et al., 2019) independently increased the odds of reporting sleep disturbances. Interestingly, additional risk factors emerged only among those under 65, including working in settings at risk for COVID-19 or being unemployed, reporting high physical activity levels before the pandemic, suffering from multiple diseases, and functional dependency (Silva-Costa et al., 2015). In keeping with these findings, in previous investigations, individuals with lower socioeconomic status or unemployed reported more frequent sleep complaints (Grandner et al., 2010; Linton & Bryngelsson, 2000). Among the professional categories, healthcare workers are particularly affected by sleep disturbances, and, during the pandemic, an even greater burden emerged for employees in risky settings (Sørengaard & Saksvik-Lehouillier, 2022; Wańkowicz et al., 2020). As far as physical activity is concerned, several authors highlighted that low physical activity levels might worsen sleep quality, and this negative effect may be partly due to underlying poorer health status. Interestingly, some other works found that also very high physical activity levels were associated with an increased insomnia risk, which may be linked to personality traits or coexistent stressful conditions (Wang & Boros, 2021). An alternative hypothesis is that the pandemic-related restrictions, especially during the lockdown, limited physical activity for those who used to perform regular exercise. Such a change negatively influences their health, including sleep quality. Finally, in the younger EPICOVID-19 participants who got COVID-19 had worse sleep quality. This result was observed in other works that found long-COVID-19 symptoms related to COVID-19 history both in previously hospitalised and non-hospitalised individuals (El Sayed et al., 2021; Mekhael et al., 2022; Mohamed-Hussein et al., 2021).

Among the limitations of this work, first, we did not collect data on sleep disorders and stress before the COVID-19 pandemic, and given the strong cross-sectional association observed between fear related to COVID-19, sleep and stress, we strengthen the need for longitudinal works to confirm our results and exclude reverse causality. Second, we assessed fear related to COVID-19 with an ad hoc questionnaire created for the survey and not yet validated. Third, our study is based on a self-selected sample of adult volunteers living in the Italy, leading to a poor representativeness of the sample especially for the oldest age group not used to technology. In the same way, the requirement of technological capabilities for participation in the survey might have determined a further selection bias of those

with higher educational and socioeconomic levels, especially among the older age group. Lastly, no information on the use of drugs for sleep disorders was available.

On the other hand, the strengths of the study are the large sample size and the set of variables collected through validated scales. Furthermore, a point of novelty and robustness of the work lies in evaluating the interplay between fear related to COVID-19 and stress in relation to the presence of sleep disorders in different subgroups of individuals through advanced statistical analyses.

In conclusion, during the pandemic, fear related to COVID-19 was associated with the presence of sleep disturbances both directly and indirectly through stress. The profile of the individuals who experienced sleep disturbances was characterised by specific sociodemographic and medical factors such as age, sex, employment, stress levels, chronic diseases, and dependency. Since the COVID-19 pandemic represented a burdensome model for the population, this study highlights the need for targeted interventions both to prevent sleep disturbances and to improve sleep quality by acting on psychological well-being.

AUTHOR CONTRIBUTIONS

Federica Prinelli and Fulvio Adorni are the project administrator. Caterina Trevisan, Antonio De Vincentis and Marianna Noale wrote the original draft of the manuscript. Federica Prinelli, Fulvio Adorni and Marianna Noale had full access to all data in the study. Marianna Noale take responsibility for the accuracy of data analysis. Caterina Trevisan, Antonio De Vincentis, Marianna Noale, Stefania Maggi, Raffaele Antonelli Incalzi, Claudio Pedone, Federica Prinelli, Andrea Giacomelli, Loredana Fortunato, Sabrina Molinaro, and Liliana Cori contributed in the study concept, carefully edited and revised the manuscript and interpreted the results. All authors accepted the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

Aggregated data will be made available on reasonable request to the corresponding author.

ETHICS STATEMENT

The Ethics Committee of the Istituto Nazionale per le Malattie Infettive IRCCS Lazzaro Spallanzani approved the EPICOVID19 study protocols (first phase No. 70, 12/4/2020; second phase No. 249, 14/1/2021

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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