Sleep Medicine xxx (xxxx) xxx

Contents lists available at ScienceDirect

Sleep Medicine

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

Highlights

- Cognitive and somatic pre-sleep arousal were widely diffuse during the lockdown.
- Depression and stress were main predictors of sleep quality and pre-sleep arousal.
- Having children and increased time spent in home predicted poor sleep quality.
- Young age, eveningness and late participation predicted cognitive pre-sleep arousal.
- Female gender and absence/interruption of work predicted somatic pre-sleep arousal.

https://doi.org/10.1016/j.sleep.2021.10.006

Please cite this article as: M. Gorgoni, S. Scarpelli, A. Mangiaruga *et al.*, Pre-sleep arousal and sleep quality during the COVID-19 lockdown in Italy, Sleep Medicine, https://doi.org/10.1016/j.sleep.2021.10.006

Sleep Medicine xxx (xxxx) xxx

Contents lists available at ScienceDirect

Sleep Medicine

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

Original Article

Pre-sleep arousal and sleep quality during the COVID-19 lockdown in Italy

Maurizio Gorgoni [a], Serena Scarpelli [a], Anastasia Mangiaruga [b], Valentina Alfonsi [c], Maria R. Bonsignore [d], Francesco Fanfulla [e], Luigi Ferini-Strambi [f], Lino Nobili [g, h], Giuseppe Plazzi [i, j], Luigi De Gennaro [a, c, *], Board of the Italian Association of Sleep Medicine (AIMS)

[a] Department of Psychology, Sapienza University of Rome, Rome, Italy
[b] Department of Medical and Surgical Sciences, University of Bologna, Bologna, Italy
[c] IRCCS Fondazione Santa Lucia, Rome, Italy
[d] PROMISE Department, University of Palermo, and IRIB-CNR, Palermo, Italy
[e] Sleep Medicine Unit, Clinical and Scientific Maugeri Institutes, Scientific Institute of Pavia IRCCS Pavia, Italy
[f] Sleep Disorders Center, Vita-Salute San Raffaele University, Milan, Italy
[g] Child Neuropsychiatry Unit, IRCCS Istituto Giannina Gaslini, Genoa, Italy
[h] Department of Medical and Surgical Neuroscience and Rehabilitation (DINOGMI), University of Genoa, Genoa, Italy
[i] Department of Biomedical and Neuromotor Sciences (DIBINEM), University of Bologna, Bologna, Italy
[j] IRCCS Istituto delle Scienze Neurologiche di Bologna, Bologna, Italy

ARTICLE INFO

Article history:
Received 10 May 2021
Received in revised form
18 September 2021
Accepted 9 October 2021
Available online xxx

Keywords:
COVID-19 pandemic
Sleep quality
Pre-sleep arousal
Stress
Depression

ABSTRACT

Objective: The COVID-19 pandemic has strongly affected daily habits and psychological wellbeing, and many studies point to large modifications in several sleep and sleep-related domains. Nevertheless, pre-sleep arousal during the pandemic has been substantially overlooked. Since hyperarousal represents one of the main factors for the development and the perpetuation of chronic insomnia disorder, the assessment of variables associated with high levels of pre-sleep arousal during the pandemic is clinically relevant. The study aimed to assess the prevalence and predictors of perceived sleep quality and pre-sleep arousal in an Italian sample during the COVID-19 lockdown.

Methods: We used an online survey to collect self-reported sociodemographic, environmental, clinical, sleep, and sleep-related data. Our final sample included 761 participants.

Results: Beyond a high frequency of poor sleep quality, depressive and stress symptoms, our results show that almost half of the sample suffered from clinically relevant levels of at least one component (ie, cognitive, somatic) of pre-sleep arousal. Subjects with greater pre-sleep arousal exhibited poorer sleep quality. Also, sleep quality was strongly associated with somatic and cognitive pre-sleep arousal. Regarding the predictors of sleep and sleep-related measures, depressive and event-related stress symptoms were the main factors associated with both poor sleep quality and pre-sleep arousal components. Moreover, specific sociodemographic and environmental variables were uniquely related to sleep quality, cognitive or somatic pre-sleep arousal.

Conclusions: These findings suggest that the assessment of specific sleep-related factors (ie, pre-sleep arousal), together with more global measures of sleep quality, may be crucial to depict the complex impact of the pandemic on sleep, and to help prevent and counteract the spread of insomnia symptoms.

1. Introduction

The COVID-19 pandemic and the countermeasures to contain its spread have pervasively influenced daytime and nighttime habits and quality of life worldwide. A growing body of evidence points to

* Corresponding author. Department of Psychology, University of Rome "Sapienza", 00185, Rome, Italy.
E-mail address: luigi.degennaro@uniroma1.it (L. De Gennaro).

https://doi.org/10.1016/j.sleep.2021.10.006
1389-9457/

a negative impact of the pandemic on mental health, with increased stress, depression, and anxiety [1,2].

Sleep-related psychophysiological processes are strictly linked to environmental modifications, social changes, and emotional condition. Consistently, sleep alterations during the pandemic have been widely reported. A recent meta-analysis [3] points to a global pooled prevalence of sleep problems among all the considered populations of 35.7% in the COVID-19 pandemic. In this context, Italy exhibited a higher pooled sleep problems prevalence rate of 55% [3].

Many studies aimed to assess the effect of the lockdown on sleep focused their attention on self-reported global indices of sleep quality. Indeed, among the instruments used to assess self-reported sleep features during the COVID-19 pandemic worldwide, the Pittsburgh Sleep Quality Index (PSQI [4]) was the most frequently used [3]. The PSQI represents one of the most commonly used methods assessing subjective sleep quality in both research and clinic. Specifically, it is a self-report questionnaire to evaluate seven sleep domains (ie, sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, daytime dysfunction) that, taken together, provide a global score of sleep quality.

Beyond the assessment of overall sleep quality, several studies also provided information on specific sleep and sleep-related features during the pandemic, like bedtime and waketime [5–9], sleep latency [5,6,8,10,11], sleep efficiency [5,10], sleep duration [6,12,13], sleep disturbances [6,7,10,14,15], dysfunctional sleep-related beliefs [16,17], and oneiric activity [18–24]. At present, the assessment of these specific variables depicts a complex scenario in which the pandemic has had prominent deleterious effects on sleep, as predicted in April 2020 by the European Academy for Cognitive-Behavioural Treatment of Insomnia [25]. Moreover, people with pre-existent sleep disorders may represent a more fragile population with respect to sleep alterations associated with specific pandemic-related aspects [25–28]. Several self-reported sleep characteristics collected during the lockdown are associated with the psychological status, mainly in terms of stress, depression, and anxiety [15,29,30], as well as sociodemographic and COVID-19 related variables [29–31].

Among sleep and sleep-related factors, the perceived level of pre-sleep arousal during the lockdown has been substantially overlooked by previous studies. This term refers to the state-dependent level of cognitive and somatic arousal experienced before bedtime, which can interfere with the individual ability to begin and maintain sleep [32–34]. Cognitive arousal symptoms include worries, sustaining thoughts, and active/racing mind before bedtime. Somatic arousal includes physical symptoms like high heart rate, nervous and bodily tension, and breathing difficulties. Many experimental findings and current theoretical models support the notion of hyperarousal as one of the main factors for the development and the perpetuation of chronic insomnia disorder [32–34]. Moreover, pre-sleep arousal seems to have a mediating role in the relationship between perceived stress during the day and subjective sleep quality [35,36]. In this view, starting from the observation of frequent stress-related symptoms [11,37] and the alarming prevalence of insomnia symptomatology in Italy during the COVID-19 outbreak [15], the assessment of pre-sleep arousal during the pandemic, together with the evaluation of self-reported global sleep quality, and the identification of factors that can predict them may be of crucial clinical significance. In particular, the detection of specific sociodemographic, environmental and clinical factors associated with pre-sleep arousal and sleep quality may help to target populations mainly at risk of insomnia development.

Therefore, the aim of the present study was to assess prevalence and predictors of perceived sleep quality and pre-sleep arousal in an Italian sample during the COVID-19 lockdown.

2. Methods

2.1. Design and participants

The Italian Association of Sleep Medicine board (Associazione Italiana Medicina del Sonno – AIMS) designed a cross-sectional study to assess the predictors of sleep quality and pre-sleep arousal during the COVID-19 lockdown. We used an online survey shared on several social media (Facebook, Twitter, Instagram, the AIMS website) to collect data from an Italian sample. User exposure to the survey was free (ie, it was not determined by specific algorithms). The survey was enabled from 01/04/2020 to 10/06/2020. For the present analyses, we considered data collected until the last day of the first Italian lockdown (May 4, 2020). The choice to focus exclusively on the lockdown period was based on findings suggesting that specific sleep and stress variables may exhibit large modifications during different phases of the pandemic (eg, according to changes in the restrictive measures) [38–42]. Since pre-sleep arousal has never been assessed during the COVID-19 pandemic, we conservatively decided to limit our analysis to the circumscribed period of the lockdown. Each participant declared an explicit agreement to participate to the research after reading the informed consent. The participant could withdraw from the compilation of the survey without data saving at any moment. No monetary compensation was provided. Only participants with age $\geq$18 y were considered for the analyses. The study was approved by the Institutional Review Board of the Department of Psychology, Sapienza University of Roma (# 0000585, 31/03/2020) and conducted in accordance with the Declaration of Helsinki.

2.2. Materials

Sociodemographic data and COVID-19 related information: a questionnaire was administered to collect sociodemographic data and COVD-19 related information. In particular, the following data were collected: gender, age, education, working during the lockdown, Italian area, having a partner, having children, cohabitation during the lockdown, knowing a relative/friend infected with SARS-CoV2, home size, lockdown-related changes in hours-per-day spent in home (ie, we asked the participant to separately report the h/d spent in home before and during the lockdown and then we calculated the lockdown vs. pre-lockdown difference), lockdown-related changes in hours-per-week spent playing sports (ie, we asked the participant to separately report the h/w spent playing sports before and during the lockdown and then we calculated the lockdown vs. pre-lockdown difference).

Subjective distress: the Italian version of the Impact of Event Scale (IES) [43] was used to assess event-related traumatic stress. This scale was first developed by Horowitz [44]. It is a self-reported questionnaire composed by 15 items. Total score $\geq$26 indicate moderate-to-severe stressful impact. We asked the participants to refer to a traumatic event related to the pandemic during the last week: "We kindly ask you to answer referring to the period you are living concerning the COVID-19 emergency. Please, refer to the last seven days to answer these questions". Subsequently, we controlled the participants' compliance, confirming that all reported stressful events were pandemic-related. Specifically, a single researcher (M.G., psychologist) checked the individual responses and defined

if the content was pandemic-related (ie, the event reported was directly referred to the restrictive measures or the course of the pandemic). In the current sample, the Cronbach's alpha was 0.86.

Depressive symptoms: the Beck Depression Inventory-II (BDI-II; [45]) was administered to assess depressive symptoms. It is a self-reported questionnaire consisting of 21 multiple-choice questions. Each answer provides scores from 0 to 3, which positively correlate with the severity of depressive symptoms. Total scores >13 point to the presence of depressive disorder. The Cronbach's alpha was 0.90 in the present study.

Sleep Quality: the Italian adaptation of the Pittsburgh Sleep Quality Index (PSQI; [46]) was administered to investigate sleep quality. It is a self-reported questionnaire consisting of 19 items. The results are about partial scores in seven sub-scales and a sleep quality global score. A PSQI global score >5 indicates a poor subjective sleep quality. The Cronbach's alpha was 0.78 in the current sample.

Pre-sleep arousal: the Pre-Sleep Arousal Scale (PSAS; Italian adaptation, see Ref. [47]) has been used to assess pre-sleep arousal [48]. It is a self-reported questionnaire consisting of 16 items for evaluating somatic (eight items) and cognitive (eight items) arousal experienced at bedtime while attempting to fall asleep. We adopted pathological cut-off scores of $\geq$14 and $\geq$ 20 for the somatic and cognitive subscale, respectively [49]. In the present sample, the Cronbach's alpha was 0.87 for the cognitive scale and 0.83 for the somatic scale.

Circadian preference: participants' chronotype was assessed using the Italian reduced version of the Morningness-Eveningness Questionnaire (rMEQ; [50]). It is a self-assessment questionnaire consisting of five items. The rMEQ score ranges from 4 to 25: higher scores point to morningness preference. We divided participants in evening-type, neutral-type, and morning-type according to the cut-off criteria. The Cronbach's alpha was 0.64 in the current study.

2.3. Statistics

The statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 25.0. Descriptive analyses were conducted to outline sociodemographic, COVID-19 related, clinical and subjective sleep features of the sample. All variables were presented as absolute (n) and relative (%) frequency. Moreover, means and standard deviations (SD) were presented for continuous variables.

In order to assess differences in sleep quality between groups with different levels of pre-sleep arousal, unpaired t-tests were performed. Specifically, using the PSQI global score as dependent variable, subjects with low (ie, below the cut-off) cognitive PSAS score were compared with those exhibiting clinically relevant cognitive PSAS scores, and subjects with low somatic PSAS score were compared with those showing clinically relevant somatic PSAS score. Moreover, Pearson's correlation coefficients were computed to assess the relationship between PSQI global scores and both cognitive and somatic PSAS scores.

Binary multivariable logistic regression models were performed to assess the best predictor of sleep quality (PSQI), cognitive pre-sleep arousal (PSAS-cognitive), and somatic pre-sleep arousal (PSAS-somatic), respectively. Specifically, PSQI, PSAS-cognitive, and PSAS-somatic scores were dichotomized according to their specific cut-off and considered dependent variables. For each dependent variable, the following variables were assessed as potential predictors: gender (Male; Female), age, working during the lockdown (No; Yes), having children (No; Yes); having a partner (No; Yes); cohabitation (Alone; With others); Italian area (North; Centre-South); COVID-19 infected relatives/friends (No; Yes), lockdown-related changes (ie, lockdown vs. pre-lockdown difference) in hours-per-day spent in home, lockdown-related changes (ie, lockdown vs. pre-lockdown difference) in hours-per-week spent playing sports, home size (sq. m.); time of survey participation (day), depression (BDI score $\leq$13; >13), event-related stress (IES score $\leq$25; >25), chronotype (rMEQ score: Neutral-type; Evening-type; Morning-type). We entered the variables simultaneously and calculated the adjusted odds ratio (aOR) to control for the other predictors in the model.

Before running the regression analyses, we checked for collinearity among the independent variables. No variance inflation factor $\geq$5 was found.

For each analysis, p-values < 0.05 were considered statistically significant.

3. Results

3.1. Descriptive features of the sample

We received 888 questionnaires. The first questionnaire was received on 01/04/2020, the last one on 08/06/2020. We excluded: questionnaires received after the end of the Italian lockdown (ie, 04/05/2020); participants located outside of Italy during the lockdown; participants infected with SARS-CoV2; participants with age <18 years; participants with missing data in the variables of interest (Fig. 1). The final sample considered for the analyses included 761 participants.

Sociodemographic, COVID-19 related, sleep, and clinical characteristics of our sample are reported in Table 1. PSQI, PSAS-cognitive, PSAS-somatic and IES mean scores were above the respective cut-off scores. A large frequency of poor sleep quality, cognitive and somatic pre-sleep arousal, event-related stress, and depressive symptoms can be observed.

3.2. Relationship between sleep quality and pre-sleep arousal

Compared to subjects with low pre-sleep arousal, those with clinically relevant pre-sleep arousal scores exhibited significantly poorer global sleep quality (ie, PSQI global score) in both the cognitive (low cognitive pre-sleep arousal: mean PSQI score ± SD = 4.59 ± 2.59; clinically relevant cognitive pre-sleep arousal: 7.73 ± 3.22; t = 14.84; p < 0.0001) and somatic (low somatic pre-sleep arousal: 4.91 ± 2.81; clinically relevant somatic pre-sleep arousal: 7.70 ± 3.26; t = 12.65; p < 0.0001) pre-sleep

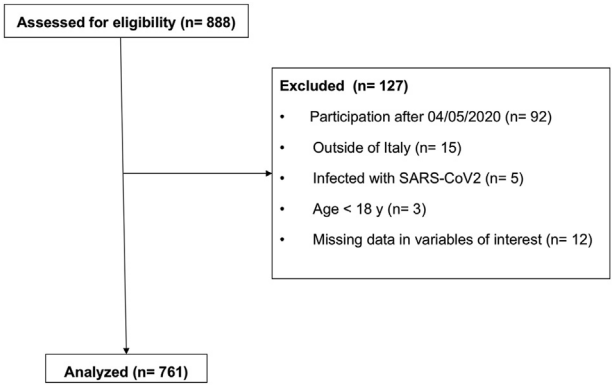

Fig. 1. Description of the participants' enrolment.

Table 1
Demographic, COVID-19 related, clinical and sleep characteristics of the sample.

	Overall sample (n = 761)	
	N	%
Demographic and COVID-19 related features		
Gender		
Male	192	25.2
Female	569	74.8
Age (Mean ± SD: 36.20 ± 14.32 y)		
18–25	230	30.2
26–30	136	17.9
31–40	145	19.1
41–50	92	12.1
>50	158	20.8
Education		
Middle school	15	2
High school	267	35.1
Undergraduate/Graduate	446	58.6
Post-graduate	33	4.3
Working during the lockdown		
No	393	51.6
Yes	368	48.4
Italian area		
North	352	46.3
Center-South	409	53.7
Having a partner		
No	268	35.2
Yes	493	64.8
Having children		
No	561	73.7
Yes	200	26.3
Cohabitation during the lockdown		
No	92	12.1
Yes	669	87.9
Knowing a relative/friend infected by COVID-19		
No	384	50.5
Yes	377	49.5
Home size (Mean ± SD: 113.29 ± 67.60 sq. m.)		
≤80	276	36.3
81–130	306	40.2
≥131	179	23.5
h/day in home: lockdown vs. pre-lockdown difference (Mean ± SD: 9.58 ± 4.24 h)		
Decreased or equal	30	3.9
Increased	731	96.1
h/week playing sports: lockdown vs. pre-lockdown difference (Mean ± SD: -0.67 ± 3.87 h)		
Decreased or equal	534	70.2
Increased	227	29.8
Sleep and clinical features		
rMEQ		
Evening type	169	22.2
Neutral type	383	50.3
Morning type	209	27.5
PSQI (Mean ± SD: 6.09 ± 3.31)		
PSQI ≤5	365	48
PSQI >5	396	52
PSAS-Cognitive (Mean ± SD: 19.96 ± 7.55)		
PSAS-Cognitive ≤19	396	52
PSAS-Cognitive >19	365	48
PSAS-Somatic (Mean ± SD: 14.02 ± 5.86)		
PSAS-Somatic ≤13	438	57.6
PSAS-Somatic >13	323	42.4
BDI (Mean ± SD: 12.37 ± 9.07)		
BDI ≤13	484	63.6
BDI >13	277	36.4
IES (Mean ± SD: 30.46 ± 8.27)		
IES ≤25	234	30.7
IES >25	527	69.3

Abbreviations: BDI, Back Depression Inventory; IES, Impact of Event Scale; PSQI, Pittsburgh Sleep Quality Index; PSAS, Pre-Sleep Arousal Scale; rMEQ, reduced Morningness-Eveningness Questionnaire; SD, Standard Deviation.

arousal domain. Moreover, PSQI scores exhibited a positive significant correlation with both PSAS-cognitive ($r = 0.55$; $p < 0.0001$) and PSAS-somatic scores ($r = 0.46$; $p < 0.0001$).

3.3. Predictors of sleep quality during the lockdown

Multiple binary logistic regression performed on sleep quality (PSQI) provided a significant model (likelihood ratio: chi-squared = 123.055, p < 0.0001, Negelkerke's $R^2 = 0.199$). The results (Fig. 2) showed that having children (p = 0.018; aOR = 1.891; 95% confidence intervals [CI] = 1.113–3.213), lockdown-related modification in h/d spent in home (p = 0.018; aOR = 1.047; 95% CI = 1.008–1.088), depression (p < 0.0001; aOR = 3.034; 95% CI = 2.125–4.332), and event-related stress (p < 0.0001; aOR = 2.530; 95% CI = 1.753–3.650) were significant predictors of sleep quality. Specifically, having children, greater increase in the number of h/d spent in home during the lockdown, exhibiting depressive symptoms and moderate-to-severe event-related stress were associated with poor sleep quality. Starting from the observation of having children as significant predictor, we perform a further multiple binary logistic regression model on sleep quality, using the same potential predictors but splitting the variable "having children" according with children ages (0–9 y; 9–14 y; 14–18 y; 18–21 y; >21 y). We observed a significant model (likelihood ratio: chi-squared = 125.868, p < 0.0001, Negelkerke's $R^2 = 0.203$), with having 0–9 y old children (p = 0.006; aOR = 2.776; 95% CI = 1.346–5.726), lockdown-related modification in h/d spent in home (p = 0.019; aOR = 1.047; 95% CI = 1.008–1.089), depression (p < 0.0001; aOR = 3.158; 95% CI = 2.207–4.517), event-related stress (p < 0.0001; aOR = 2.560; 95% CI = 1.771–3.700) were significant predictors of sleep quality (Figure S1). In particular, having 0–9 y old children, greater increase in the number of h/d spent in home during the lockdown, occurrence of depressive symptoms, and moderate-to-severe event-related stress were associated with poor sleep quality.

3.4. Predictors of pre-sleep arousal during the lockdown

Multiple binary logistic regression performed on PSAS-cognitive provided a significant model (likelihood ratio: chi-squared = 199.407, p < 0.0001, Negelkerke's $R^2 = 0.308$). Results (Fig. 3) showed that age (p = 0.020; aOR = 0.978; 95% CI = 0.960–0.996), time of survey participation (p = 0.035; aOR = 1.027; 95% CI = 1.002–1.053), depression (p < 0.0001; aOR = 3.704; 95% CI = 2.579–5.319), event-related stress (p < 0.0001; aOR = 3.234; 95% CI = 2.167–4.827), Evening chronotype (p < 0.0001; aOR = 2.547; 95% CI = 1.644–3.946) were significant predictors of cognitive pre-sleep arousal. Specifically, younger age, later participation to the survey (ie, increased time from the beginning of the lockdown), exhibiting depressive symptoms, moderate-to-severe event-related stress, and evening chronotype were associated with clinically relevant pre-sleep cognitive arousal levels.

Multiple binary logistic regression performed on PSAS-somatic provided a significant model (likelihood ratio: chi-squared = 196.751, p < 0.0001, Negelkerke's $R^2 = 0.306$). Results (Fig. 4) showed that gender (p = 0.007; aOR = 1.764; 95% CI = 1.167–2.666), work condition during the lockdown (p = 0.043; aOR = 0.696; 95% CI = 0.490–0.988), depression (p < 0.0001; aOR = 3.976; 95% CI = 2.786–5.676), and event-related stress (p < 0.0001; aOR = 3.646; 95% CI = 2.392–5.557) were significant predictors of somatic pre-sleep arousal. Specifically, female gender, absence/interruption of work during the lockdown, exhibiting depressive symptoms and moderate-to-severe event-related stress were associated with clinically relevant somatic pre-sleep arousal levels.

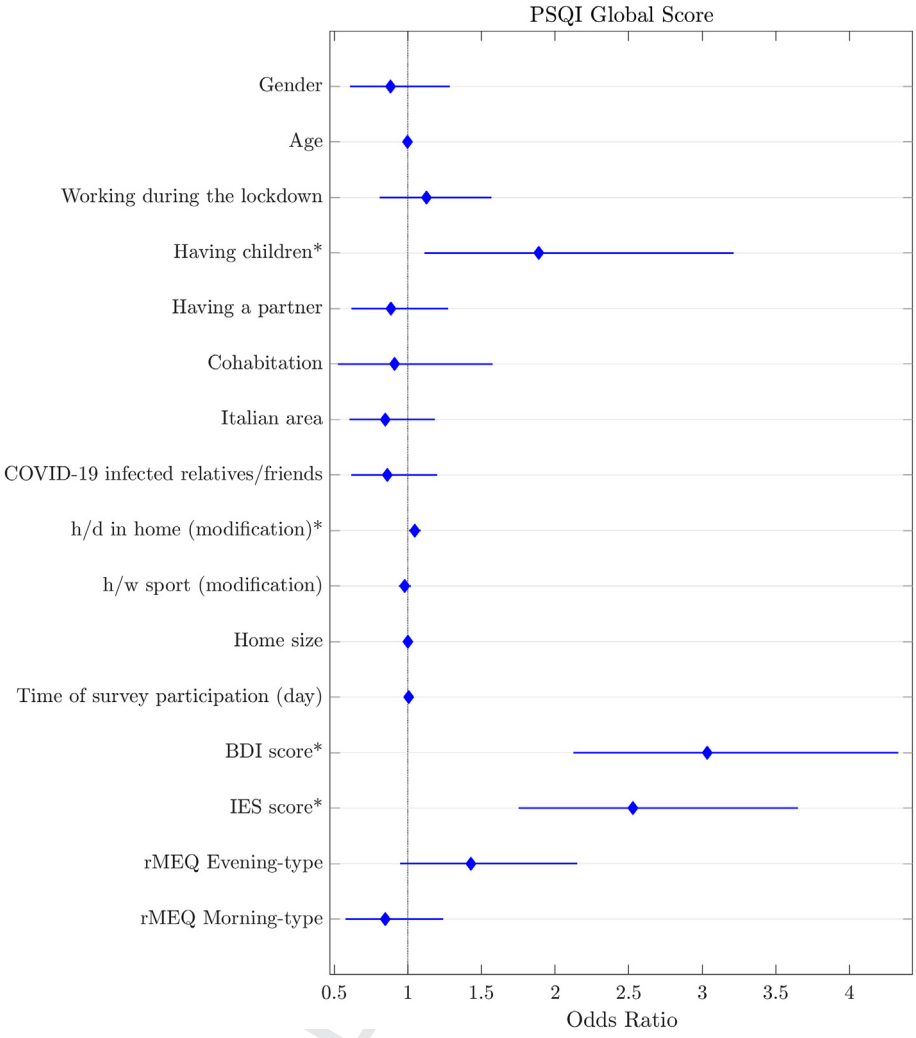

Fig. 2. Multiple binary logistic regression model with PSQI global score (low and high sleep quality) as dependent variable. Graphic representation of odds ratio and relative 95% confidence intervals for each predictor: gender (reference: male), age, working during the lockdown (reference: no), having children (reference: no), having a partner (reference: no), cohabitation (reference: alone), Italian area (reference: north), COVID-19 infected relatives/friends (reference: no), lockdown vs. pre-lockdown difference in the number of daily hours spent in home, lockdown vs. pre-lockdown difference in the number of weekly hours spent doing sports, home size, time of survey participation, BDI (reference: absence of depressive symptoms), IES (reference: subclinical/mild symptoms), rMEQ (reference: neutral type). Independent significant predictors for each outcome are marked with asterisks.

4. Discussion

To the best of our knowledge, this is the first study to assess the prevalence and predictors of pre-sleep arousal during the COVID-19 pandemic, together with self-reported sleep quality. Overall, our results highlight that a) the experience of pre-sleep arousal was widely diffuse in our sample (48% cognitive pre-sleep arousal; 42.4% somatic pre-sleep arousal), b) subjects with clinically relevant pre-sleep arousal exhibit lower sleep quality, c) sleep quality is strongly associated with both cognitive and somatic pre-sleep arousal levels, d) event-related stress and depressive symptoms represent the strongest predictors for both low self-reported sleep quality and great cognitive and somatic perceived pre-sleep arousal during the lockdown and e) specific sociodemographic and COVID-19 related variables seems to be associated only with specific sleep and sleep-related measures. In particular, poor sleep quality was predicted by having children (particularly of age <9 y) and a greater lockdown-related increase of the time spent at home. Cognitive pre-sleep arousal was associated with younger age, participation in the survey at a later time from the beginning of the lockdown, and evening chronotype. Finally, somatic pre-sleep arousal was associated with female gender and absence/interruption of work during the lockdown.

4.1. Pre-sleep arousal during the lockdown

Beyond confirming an elevated frequency of poor sleep quality, depressive symptoms, and event-related stress during the COVID-19 pandemic in Italy [5,10,11,15,22,30,37,51–54], we found that almost half of our sample suffers from clinically relevant levels of at least one component of pre-sleep arousal, highlighting the relevant frequency of this experience during the lockdown. Crucially, subjects with clinically relevant pre-sleep arousal levels exhibited poorer sleep quality, and both somatic and cognitive pre-sleep arousal were strongly associated with the level of sleep quality. Therefore, considering the role of hyperarousal for the development and the perpetuation of chronic insomnia disorder [32–34] we suggest that the level of arousal in correspondence of the sleep onset process during the pandemic should be widely considered by researchers and clinicians. Obviously, our observation should be replicated on larger samples, and longitudinal evaluation should be performed to clarify the lockdown's impact on pre-sleep arousal.

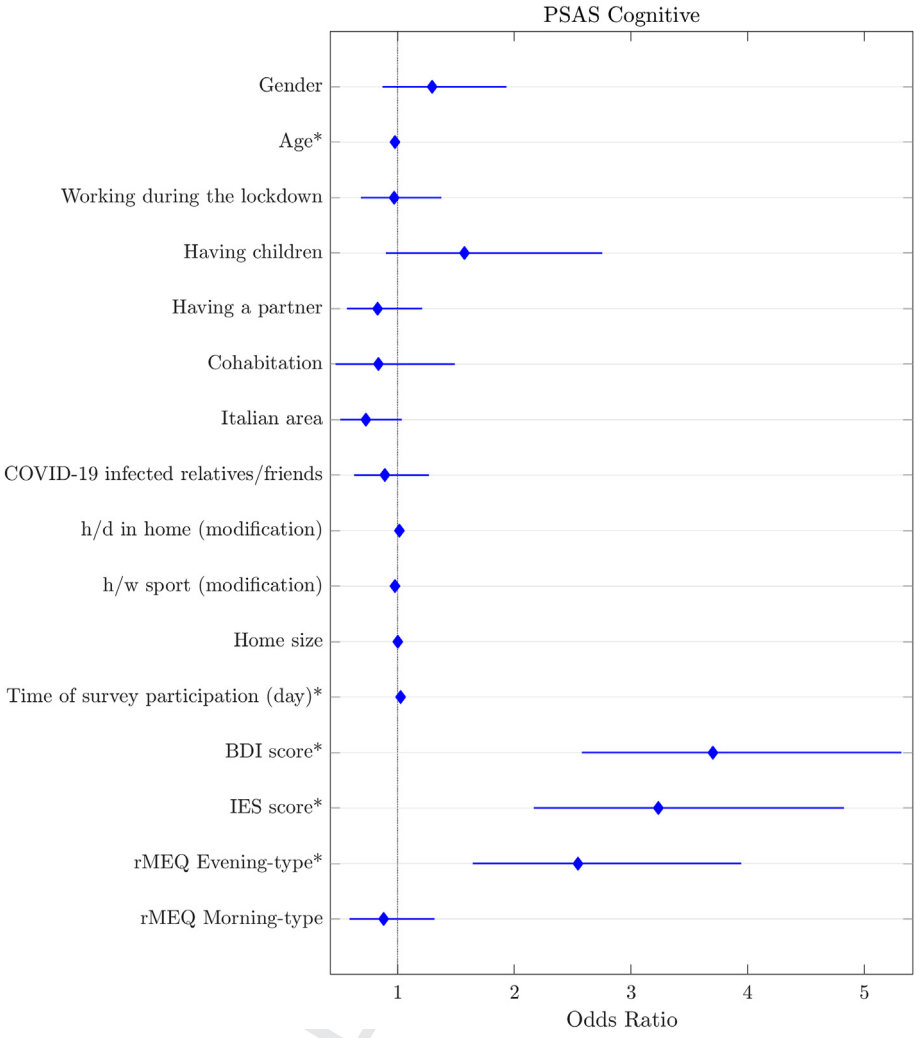

Fig. 3. Multiple binary logistic regression model with PSAS cognitive score (low and high sleep quality) as dependent variable. Graphic representation of odds ratio and relative 95% confidence intervals for each predictor: gender (reference: male), age, working during the lockdown (reference: no), having children (reference: no), having a partner (reference: no), cohabitation (reference: alone), Italian area (reference: north), COVID-19 infected relatives/friends (reference: no), lockdown vs. pre-lockdown difference in the number of daily hours spent in home, lockdown vs. pre-lockdown difference in the number of weekly hours spent doing sports, home size, time of survey participation, BDI (reference: absence of depressive symptoms), IES (reference: subclinical/mild symptoms), rMEQ (reference: neutral type). Independent significant predictors for each outcome are marked with asterisks.

4.2. Stress and depressive symptoms as common predictors for sleep quality and pre-sleep arousal

The only common variables associated with both pre-sleep arousal components and global sleep quality were event-related stress and depressive symptoms, which also represented the strongest predictors in all of the performed regression models. The relationship between sleep problems and stress is well-known [55–59] and a large percentage of subjects with post-traumatic stress disorder (PTSD) suffers from sleep problems [60]. Experimentally induced stress is followed by greater arousal at bedtime, inducing poorer sleep in both good and poor sleepers [61–63]. Moreover, pre-sleep arousal seems to mediate the association between sleep quality and stress [35,36]. Depression is also frequently associated with both poor sleep quality [64] and pre-sleep arousal [48,65].

The association between sleep problems and different stress-related measures during the COVID-19 pandemic has been widely documented [5,11,29,30,37,66–69]. Also, during the pandemic, depressive symptoms have been observed in association with insomnia severity [15], low sleep quality [5,29,30,70], false beliefs on sleep [16], greater nightmare frequency [23] and dream frequency and intensity [22], and negative emotions in dreams [22]. Beyond confirming the association between the emotional condition and poor sleep quality during the lockdown, we extend the relationship to both cognitive and somatic pre-sleep arousal. Therefore, independently from the observed influence of specific sociodemographic and contextual factors on particular sleep variables (see below), our results index that populations with depressive symptoms and greater event-related stress represent those with higher risk of cognitive and somatic pre-sleep arousal and poor sleep quality during the lockdown.

4.3. Specific predictors of cognitive and somatic pre-sleep arousal

Evening chronotype was a specific predictor of pre-sleep cognitive arousal. The present literature suggests that evening types are characterized by more irregular sleep–wake cycle, poor sleep quality, greater daytime sleepiness and higher inclination to insomnia [71–75]. Moreover, eveningness is associated with higher susceptibility to stress [76], reduced emotional stability [77,78], depression [79] and greater physiological arousal at rest and during

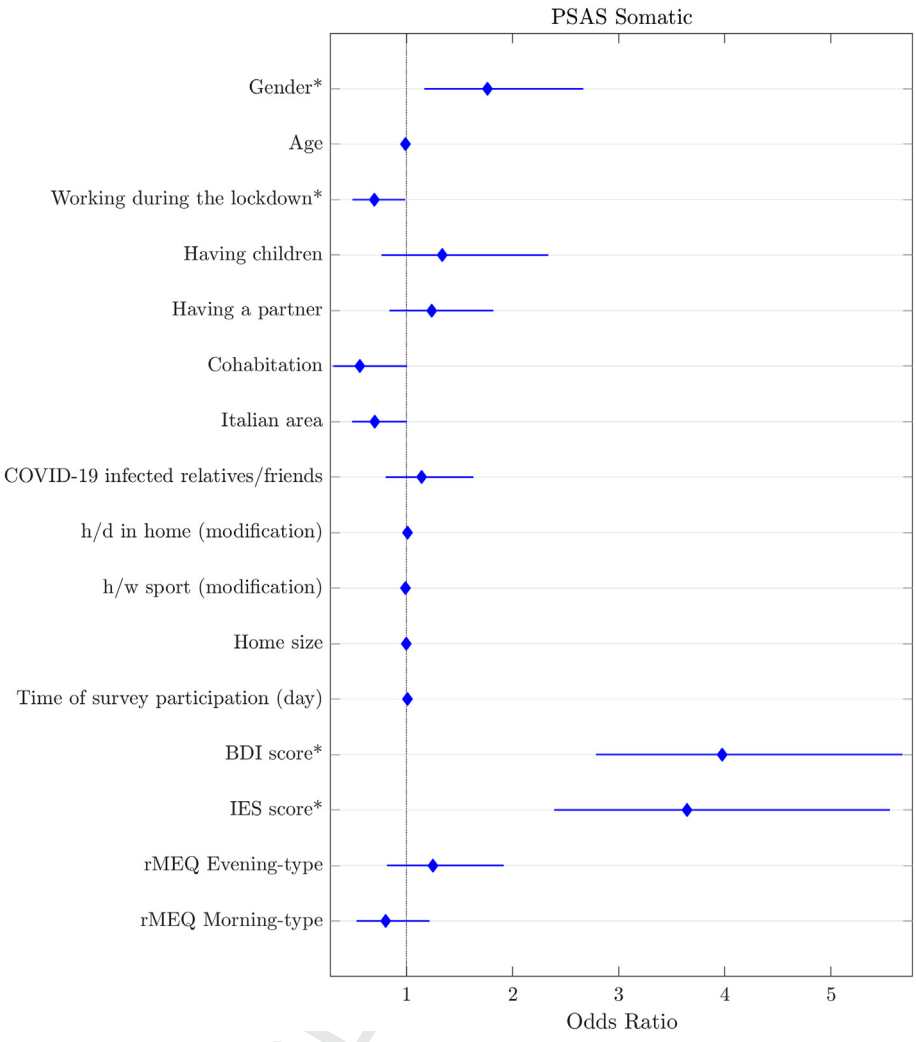

Fig. 4. Multiple binary logistic regression model with PSAS somatic score (low and high sleep quality) as dependent variable. Graphic representation of odds ratio and relative 95% confidence intervals for each predictor: gender (reference: male), age, working during the lockdown (reference: no), having children (reference: no), having a partner (reference: no), cohabitation (reference: alone), Italian area (reference: north), COVID-19 infected relatives/friends (reference: no), lockdown vs. pre-lockdown difference in the number of daily hours spent in home, lockdown vs. pre-lockdown difference in the number of weekly hours spent doing sports, home size, time of survey participation, BDI (reference: absence of depressive symptoms), IES (reference: subclinical/mild symptoms), rMEQ (reference: neutral type). Independent significant predictors for each outcome are marked with asterisks.

stress conditions [80]. A genetic study in 105,739 UK Biobank participants also demonstrated that eveningness is causally associated with lower subjective wellbeing [81]. Therefore, it is conceivable that eveningness is associated with cognitive pre-sleep arousal during a stressful situation like the pandemic. Descriptive analyses in a large Italian sample during the COVID-19 pandemic showed that subjects with evening chronotype exhibited greater insomnia severity [15]. Moreover, Salfi and coworkers [41] found that evening chronotype predicted a higher risk of poor sleep quality and moderate/severe insomnia symptoms during the second wave of COVID-19 in Italy. Also, the observed influence of the later participation in our survey may suggest that a prolonged period spent in the stressful situation represented by the lockdown may have contributed to increase the level of cognitive pre-sleep arousal. Since the epidemiological situation in Italy was getting progressively better in the final period of the lockdown, such phenomenon would be more likely attributable to persistent daily habits and environmental factors associated with home confinement. Consistently, an Italian study [82] collected data during the third and the seventh week of the lockdown, showing in the second time point greater sleep disturbances in participants who increased evening electronic device usage, while those reporting reduced screen exposure showed improved sleep quality and insomnia symptoms. Finally, younger participants exhibited a higher risk of cognitive pre-sleep arousal. During the pandemic, younger adults reported greater concerns and severity of insomnia [15], higher risk of psychological distress [11], anxiety [11,51,83], depression [16,83], greater dreams and nightmare frequency [22,23] and intensity [22]. Interestingly, while some evidence suggests that younger age was associated with poor sleep quality during the pandemic [84], several studies found no relationship between age and sleep disturbance/poor sleep quality [11,16,30,51,83]. It is possible that the evaluation of specific sleep and sleep-related domains like pre-sleep arousal may more easily allow the detection of particular age-related sleep problems during the pandemic than the assessment of global measures of sleep quality.

Concerning somatic pre-sleep arousal, female gender and absence/interruption of work during the lockdown were further significant predictors. Many studies suggest that females exhibit a higher predisposition to develop sleep problems during the pandemic [11,30,51,67,69,41,85]. It is well-known that insomnia is more frequent in women [86], which also report higher event-

related stress rates [87], and results more emotionally reactive to stress and negative stimuli [88,89]. Chen and co-workers [90] found that women had greater somatic pre-sleep arousal than men in a group of patients with suspected sleep-disordered breathing. Vochem and coworkers [91] observed that women with insomnia exhibited a greater risk of somatic pre-sleep arousal. Taken together, these results suggest that during demanding periods like the pandemic, women's stress may also be expressed with somatic pre-sleep arousal more likely than men's one. Regarding the absence of work, other studies during the pandemic suggest that unemployed subjects are more at risk to exhibit higher sleep problems [11,31,68]. Albeit no direct relationship was found between poor sleep quality and unemployment in our study, our results suggest that the latter may also be related to pre-sleep arousal, which in turn may impact sleep.

The existence of different predictors uniquely associated with cognitive or somatic pre-sleep arousal is not surprising. Indeed, many studies suggest that the cognitive and somatic domains of pre-sleep arousal exhibit differential patterns of association with several sociodemographic, psychological, and sleep variables [49,92–95]. Moreover, a recent study on twins and siblings emphasize that, beyond possible differences in the relationship with insomnia symptoms, cognitive and somatic pre-sleep arousal may have a different etiology [96]. Interestingly, the studies of Puzino and coworkers [49,95] suggest that cognitive pre-sleep arousal is more directly associated with insomnia vulnerability and perpetuation, while self-reported somatic pre-sleep arousal mainly represents an index of anxiety, impacting nighttime sleep. In this view, it could be hypothesized that the observed relationship of somatic pre-sleep arousal with female gender and absence of work would be mainly mediated by the level of anxiety. On the other hand, the role of anxiety would be secondary in the relationship of cognitive pre-sleep arousal with eveningness, younger age, and later participation to the survey. However, this hypothesis remains speculative and should be directly investigated.

4.4. Specific predictors of poor sleep quality

Concerning poor sleep quality, increased time spent in home during the lockdown and cohabitation with children (particularly younger ones) were significant predictors. Forced home confinement implies great changes in habitual routines that can potentially affect sleep, entailing modifications in work and school schedules, interruption of interpersonal relationships and rewarding activities, forced and prolonged cohabitation with family members, and reduction of daylight exposure [25]. Therefore, it is not surprising that a larger increase of time spent in home during the lockdown is associated with poor sleep quality. In this context, parents of younger children may be at higher risk for psychological distress (and in turn sleep problems), being forced to significantly rearrange childcare routines and increased difficulties to manage the balance between working schedules, house-holding and family needs. An Italian study has shown that caregivers with children, especially those with children aged <6 years, experienced more behavioral changes, including sleep alterations, than those without children [54]. One Turkish study found that subjects with children showed higher psychological distress during the pandemic than those without children [68]. Also, children's sleep has been found to be strongly affected by the pandemic [54,97–102], and a strong correlation between caregivers' discomfort and their children's malaise has been observed [54].

Therefore, an interaction between children's sleep alterations and reduced parents' sleep quality could be hypothesized. A study conducted in Israel found that mothers exhibiting greater insomnia scores more likely reported reduced sleep quality and duration in their children [103]. Moreover, mothers showing higher COVID-19 anxiety had greater insomnia symptoms and children exhibiting lower sleep quality [103]. Quarantine-related reduction of sleep quality has been found in both Italian mothers and their pre-school children (2–5 y), as well as greater emotional symptoms and self-regulation difficulties in children [100]. Also, children's self-regulatory abilities were associated with their sleep quality and that of their mothers, and similar results were found for mother's strengths and difficulties. The same research group [101] found that, beyond sleep timing delay and reduced sleep quality, school-age children (6–10 y) exhibited increased emotional, conduct and hyperactive symptoms associated with their sleep quality and boredom, and mother's psychological distress. Delayed sleep timing, worsened sleep quality and increased psychological symptoms were also observed in mothers. Interestingly, more regular sleep patterns were observed in mothers who continued to work regularly outside their homes, and greater emotional symptoms and change in time perception in those who stopped working [101]. With a different approach, our study is consistent with the present literature, showing that being a parent of children with age <9 y during the lockdown is associated with poor sleep quality.

4.5. General considerations

The body of evidence on sleep changes during the pandemic is progressively growing. The assessment of the complex relationship between the emotional, cognitive, behavioural, and environmental factors that may determine the emergence of poor sleep quality and insomnia symptoms is crucial to define how, when, and why sleep pattern can exhibit changes during the COVID-19 era. Nevertheless, several important sleep-related factors have been not considered in the literature on the pandemic. Albeit characterized by an explorative nature with intrinsic methodological limitations (see below) the present study emphasises the relevance of pre-sleep arousal during the lockdown, representing the basis for future systematic research on this crucial sleep-related variable during the pandemic.

Indeed, these findings describe for the first time the experience of pre-sleep arousal during the COVID-19 pandemic, highlighting that such condition may be frequent during the period of home confinement. Also, our results suggest that, beyond the strongest association with the emotional status (ie, stress, depression), specific environmental conditions (increased time spent at home, greater time spent in the lockdown condition, and absence/interruption of work), sociodemographic variables (having children, younger age, and female gender) and individual characteristics (evening chronotype) can differentially affect sleep quality, cognitive, and somatic pre-sleep arousal during the pandemic.

As detailed in the previous sections, several relationships were expected on the basis of the existing literature on sleep problems in general and more specifically concerning the pandemic. In particular, using a different methodological approach, our results provide further support to the notion of a relationship between poor sleep quality and cohabitation with children during the lockdown period [54]. Considering chronotype, our findings are consistent with the view of eveningness as a risk factor for sleep difficulties [15,41,71–75], based on the novel observation of an association between cognitive pre-sleep arousal and eveningness during the lockdown. Furthermore, our results are in line with the existing data reporting a relationship between female gender and somatic pre-sleep arousal [90,91], confirming it for the first time during the pandemic.

The observed relationship between younger age and cognitive pre-sleep arousal add a novel piece of knowledge to the conflicting literature on the association of age and sleep problems during the pandemic [11,16,30,51,83,84].

Other specific relationships between sleep measures and environmental variables have never been observed and represent a further novelty of the current study. In particular, it is worth noting that different sleep variables were associated with specific lockdown-dependent environmental changes: sleep quality and increased time spent in home; cognitive pre-sleep arousal and time spent in the lockdown condition; somatic pre-sleep arousal and absence/interruption of work during the lockdown.

Clearly, our analyses do not allow inferences about the reciprocal interplay between social/environmental conditions, psychological status, pre-sleep arousal, and sleep quality. Any conclusion about possible direct causal effect would be simplistic considering the complexity of the phenomenon. Also, it should be considered that the relationship between diurnal stress, pre-sleep arousal and sleep appears substantially bidirectional [104].

Albeit the present knowledge clearly points to a detrimental effect of the pandemic-related home confinement on sleep [3], several studies also suggest positive effects of the lockdown, like greater sleep time [9,12,40,105,106] and reduced social jet lag [9], probably in association with higher flexibility of social and working schedules. Beyond methodological differences between the studies, these results highlight the complex and multidirectional effect that the lockdown has had on sleep and sleep-related variables. Our observation of a differential association between specific sociodemographic and COVID-19 related variables with sleep quality, cognitive and somatic pre-sleep arousal highlight that the parallel assessment of different sleep and sleep-related features may help to disentangle such complexity and target those populations with higher risk for pandemic-related insomnia development. In other words, based on the results of our explorative analyses, we stress that a multidimensional approach (ie, the evaluation of different sleep and sleep-related measures) is needed to clearly define the effect of specific pandemic-related variables on sleep.

5. Limitations

Several limitations of our study should be considered. Although the online survey has been the widest used method to assess psychological and sleep features on large samples during the pandemic, this strategy can introduce a significant bias, attracting many subjects with emotional and/or sleep difficulties leading to a potential overrepresentation of sleep and mental health problems. Moreover, our sample was unbalanced for several sociodemographic variables. In particular, females represented more than 70% of the sample, which is a common condition in many online surveys conducted during the COVID-19 pandemic (eg, Refs. [5,11,22,23]). Also, the sample was characterized by a larger number of participants with young age (67.2% had less that 40 y), partner (64.8%), cohabitation (87.9%), and without children (73.7%), while low education level was underrepresented (only 2% of the sample reached middle school as maximum education level). These unbalanced variables may have had an impact on the present results, particularly considering the existence of sex differences in pre-sleep arousal [90] and insomnia [86], and the evidence of age-specific features in the sleep pattern [107]. In this view, great caution should be taken in generalizing these findings. The cross-sectional nature of the study limits the possible interpretation in terms of causal effects, highlighting the need for longitudinal evaluations. Also, it is worth noting that no pre-pandemic sleep data were collected, which represent relevant information in light of the evidence that the effect of the lockdown on sleep quality is not uniform and may also depend on the pre-pandemic levels of insomnia symptoms [108]. Similarly, we don't have information about the pre-lockdown clinical condition and, in turn, its possible influence on the perception of sleep quality and pre-sleep arousal during the pandemic.

Finally, it should be mentioned that outdoor individual physical activity during the lockdown in Italy was allowed only close to home. This factor has not been directly considered in our analyses and it may be potentially relevant.

6. Conclusions

Our results point to a large presence of pre-sleep arousal symptoms in our Italian sample during the lockdown, and a strong association between pre-sleep arousal and low sleep quality. Crucially, we observed that event-related stress and depression symptoms were the strongest predictors of both sleep quality and pre-sleep arousal components. On the other hand, several sociodemographic variables were uniquely associated with global sleep quality, cognitive, or somatic pre-sleep arousal. These results highlight that the assessment of specific sleep-related factors, together with more global measures of sleep quality, is crucial to depict the complex impact of the pandemic on sleep.

While a large part of the population worldwide has experienced sleep and sleep-related alterations during the lockdown, the nature and direction of such alterations are influenced by several factors and their reciprocal interplay. A wider knowledge of the variables that affected the specific sleep and sleep-related features during the pandemic can be useful to guide sleep assessment and interventions during (and after) the COVID-19 era. Considering the crucial role attributed to hyperarousal for the development and maintenance of chronic insomnia disorder [32–34] and the role of pre-sleep arousal in the relationship between stress and sleep quality [35,36], its evaluation during the pandemic can help to prevent and counteract the observed spread of insomnia symptoms [15]. In this view, the knowledge of the factors associated with pre-sleep arousal may help an early detection of those populations characterized by greater risk to develop a future clinically relevant sleep disorder during the pandemic, particularly in relation to the specific lockdown-related environmental changes underlined in the present study. Beyond clinical interventions aimed at modulating the emotional status, cognitive-behavioural psychotherapy and mindfulness-based interventions may represent accessible strategies for the management of both sleep quality and pre-sleep arousal. Unfortunately, only one study showed that one-week self-guided internet cognitive-behavioural treatments for insomnia in adults with pandemic-related situational insomnia had a favourable effect on insomnia symptoms and somatic pre-sleep arousal [109]. Prompt interventions to modulate pre-sleep arousal and sleep quality during the pandemic are needed.

Credit authorship contribution statement

Maurizio Gorgoni: Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – original draft; Visualization. Serena Scarpelli: Investigation, Formal analysis, Methodology, Data curation. Anastasia Mangiaruga: Investigation, Formal analysis, Data curation. Valentina Alfonsi: Investigation, Data curation. Maria R. Bonsignore: Conceptualization, Validation, Writing – review & editing, Visualization. Francesco Fanfulla: Conceptualization, Validation, Writing – review & editing, Visualization. Luigi Ferini-Strambi: Conceptualization, Validation, Writing – review & editing, Visualization. Lino Nobili: Conceptualization, Validation, Writing – review & editing, Visualization. Giuseppe Plazzi: Conceptualization, Validation, Writing – review & editing, Visualization. Luigi De Gennaro: Conceptualization, Methodology, Validation, Writing – original draft, Visualization, Supervision.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

None of the authors have potential conflicts of interest to be disclosed.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.10.006.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2021.10.006.

References

[1] Xiong J, Lipsitz O, Nasri F, et al. Impact of COVID-19 pandemic on mental health in the general population: a systematic review. J Affect Disord 2020;277:55–64. https://doi.org/10.1016/j.jad.2020.08.001.
[2] Torales J, O'Higgins M, Castaldelli-Maia JM, et al. The outbreak of COVID-19 coronavirus and its impact on global mental health. Int J Soc Psychiatr 2020;66(4):317–20.
[3] Jahrami H, BaHammam AS, Bragazzi NL, et al. Sleep problems during the COVID-19 pandemic by population: a systematic review and meta-analysis. J Clin Sleep Med 2021;17(2):299–313. https://doi.org/10.5664/jcsm.8930.
[4] Buysse DJ, Reynolds CF, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatr Res 1989;28:193–213.
[5] Cellini N, Canale N, Mioni G, et al. Changes in sleep pattern, sense of time and digital media use during COVID-19 lockdown in Italy. J Sleep Res 2020;29(4):e13074. https://doi.org/10.1111/jsr.13074.
[6] 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;73:1–10. https://doi.org/10.1016/j.sleep.2020.06.032.
[7] Gupta R, Grover S, Basu A, et al. Changes in sleep pattern and sleep quality during COVID-19 lockdown. Indian J Psychiatr 2020;62(4):370. https://10.4103/psychiatry.IndianJPsychiatry_523_20.
[8] Marelli S, Castelnuovo A, Somma A, et al. Impact of COVID-19 lockdown on sleep quality in university students and administration staff. J Neurol 2020. https://doi.org/10.1007/s00415-020-10056-6.
[9] Leone MJ, Sigman M, Golombek DA. Effects of lockdown on human sleep and chronotype during the COVID-19 pandemic. Curr Biol 2020;30(16):R930–1. https://doi.org/10.1016/j.cub.2020.07.015.
[10] Barrea L, Pugliese G, Framondi L, et al. Does sars-cov-2 threaten our dreams? Effect of quarantine on sleep quality and body mass index. J Transl Med 2020;18:318. https://doi.org/10.21203/rs.3.rs-33081/v2.
[11] Casagrande M, Favieri F, Tambelli R. 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.
[12] Blume C, Schmidt MH, Cajochen C. Effects of the COVID-19 lockdown on human sleep and rest-activity rhythms. Curr Biol 2020;30(14):R795–7. https://doi.org/10.1016/j.cub.2020.06.021.
[13] Hisler GC, Twenge JM. Sleep characteristics of U.S. adults before and during the COVID-19 pandemic. Soc Sci Med 2021;276:113849. https://doi.org/10.1016/j.socscimed.2021.113849.
[14] Beck F, Léger D, Fressard L, et al., Coconel Group. Covid-19 health crisis and lockdown associated with high level of sleep complaints and hypnotic uptake at the population level. J Sleep Res 2020;30(1):e13119. https://doi.org/10.1111/jsr.13119.
[15] Bacaro V, Chiabudini M, Buonanno C, et al. Insomnia in the Italian population during covid-19 outbreak: a snapshot on one major risk factor for depression and anxiety. Front Psychiatr 2020;11:579107. https://doi.org/10.3389/fpsyt.2020.579107.
[16] Idrissi AJ, Lamkaddem A, Benouajjit A, et al. Sleep quality and mental health in the context of COVID-19 pandemic and lockdown in Morocco. Sleep Med 2020;74:248–53. https://doi.org/10.1016/j.sleep.2020.07.045.
[17] Sella E, Carbone E, Toffalini E, et al. Self-reported sleep quality and dysfunctional sleep-related beliefs in young and older adults: changes in times of COVID-19 lockdown. Sleep Med 2020;81:127–35. https://doi.org/10.1016/j.sleep.2021.02.017.
[18] Schredl M, Bulkeley K. Dreaming and the COVID-19 pandemic: a survey in a US sample. Dreaming 2020;30(3):189–98. https://doi.org/10.1037/drm0000146.
[19] Iorio I, Sommatico M, Parrello S. Dreaming in the time of COVID-19: a quali-quantitative Italian study. Dreaming 2020;30(3):199–215. https://doi.org/10.1037/drm0000142.
[20] Mota NB, Weissheimer J, Ribeiro M, et al. Dreaming during the Covid-19 pandemic: computational assessment of dream reports reveals mental suffering related to fear of contagion. PLoS One 2020;15(11):e0242903. https://doi.org/10.1371/journal.pone.0242903.
[21] Pesonen AK, Lipsanen J, Halonen R, et al. Pandemic dreams: network analysis of dream content during the COVID-19 lockdown. Front Psychol 2020;11:2569. https://doi.org/10.3389/fpsyg.2020.573961.
[22] Gorgoni M, Scarpelli S, Alfonsi V, 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.
[23] Scarpelli S, Alfonsi V, Mangiaruga A, et al. Pandemic nightmares: effects on dream activity of the COVID-19 lockdown in Italy. J Sleep Res 2021;2021:e13300. https://doi.org/10.1111/jsr.13300.
[24] Wang J, Zemmelman SE, Hong D, et al. Does COVID-19 impact the frequency of threatening events in dreams? An exploration of pandemic dreaming in light of contemporary dream theories. Conscious Cognit 2021;87:103051. https://doi.org/10.1016/j.concog.2020.103051.
[25] Altena E, Baglioni C, Espie CA, 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. J Sleep Res 2020;29(4):e13052. https://doi.org/10.1111/jsr.13052.
[26] Franco B, Morais MA, Holanda ASS, et al. Impact of Covid-19 on the restless legs syndrome. Sleep Sci 2020;13(3):186–90. https://doi.org/10.5935/1984-0063.20200031.
[27] Postiglione E, Pizza F, Ingravallo F, et al. Impact of COVID-19 pandemic lockdown on narcolepsy type 1 management. Brain Behav 2021;11(1):e01955. https://doi.org/10.1002/brb3.1955.
[28] Rodrigues Aguilar AC, Frange C, Huebra L, et al. The effects of the COVID-19 pandemic on patients with narcolepsy. J Clin Sleep Med 2021;17(4):621–7. https://doi.org/10.5664/jcsm.8952.
[29] Hyun S, Hahm HC, Wong GTF, et al. Psychological correlates of poor sleep quality among U.S. young adults during the COVID-19 pandemic. Sleep Med 2021;78:51–6. https://doi.org/10.1016/j.sleep.2020.12.009.
[30] Franceschini C, Musetti A, Zenesini C, et al. Poor sleep quality and its consequences on mental health during the COVID-19 lockdown in Italy. Front Psychol 2020;11:574475. https://doi.org/10.3389/fpsyg.2020.574475.
[31] Pinto J, van Zeller M, Amorim P, et al. Sleep quality in times of Covid-19 pandemic. Sleep Med 2020;74:81–5. https://doi.org/10.1016/j.sleep.2020.07.012.
[32] Perlis ML, Giles DE, Mendelson WB, et al. Psychophysiological insomnia: the behavioural model and a neurocognitive perspective. J Sleep Res 1997;6(3):179–88.
[33] Espie CA, Broomfield NM, MacMahon KMA, et al. The attention-intention–effort pathway in the development of psychophysiologic insomnia: a theoretical review. Sleep Med Rev 2006;10(4):215–45. https://doi.org/10.1016/j.smrv.2006.03.002.
[34] Riemann D, Spiegelhalder K, Feige B, et al. The hyperarousal model of insomnia: a review of the concept and its evidence. Sleep Med Rev 2010;14(1):19–31. https://doi.org/10.1016/j.smrv.2009.04.002.
[35] Morin CM, Rodrigue S, Ivers H. Role of stress, arousal, and coping skills in primary insomnia. Psychosom Med 2003;65:259–67.
[36] Winzeler K, Voellmin A, Schäfer V, et al. Daily stress, presleep arousal, and sleep in healthy young women: a daily life computerized sleep diary and actigraphy study. Sleep Med 2014;15(3):359–66. https://doi.org/10.1016/j.sleep.2013.09.027.
[37] Forte G, Favieri F, Tambelli R, et al. 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(11):4151. https://doi.org/10.3390/ijerph17114151.
[38] Daly M, Robinson E. Psychological distress and adaptation to the COVID-19 crisis in the United States. J Psychiatr Res 2020;136:603–9. https://doi.org/10.1016/j.jpsychires.2020.10.035.
[39] Daly M, Sutin AR, Robinson E. Longitudinal changes in mental health and the COVID-19 pandemic: evidence from the UK Household Longitudinal Study. Psychol Med 2020;13:1–10. https://doi.org/10.1017/S0033291720004432.
[40] Alfonsi V, Gorgoni M, Scarpelli S, et al. COVID-19 lockdown and poor sleep quality: not the whole story. J Sleep Res 2021;30:e13368. https://doi.org/10.1111/jsr.13368.
[41] Salfi F, D'Atri A, Tempesta D, et al. Sleeping under the waves: a longitudinal study across the contagion peaks of the COVID-19 pandemic in Italy. J Sleep Res 2021:e13313. https://doi.org/10.1111/jsr.13313.
[42] Pieh C, Budimir S, Humer E, et al. 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.

[43] Pietrantonio F, De Gennaro L, Di Paolo MC, et al. The impact of event scale: validation of an Italian version. J Psychosom Res 2003;55(4):389–93. https://doi.org/10.1016/s0022-3999(02)00638-4.
[44] Horowitz M, Wilner N, Alvarez W. Impact of event scale: a measure of subjective stress. Psychosom Med 1979;41(3):209–18. https://doi.org/10.1097/00006842-197905000-00004.
[45] Beck AT, Steer RA, Brown GK. Manual for the Beck depression inventory II. San Antonio, TX: Psychological Corporation; 1996.
[46] Curcio G, Tempesta D, Scarlata S, et al. Validity of the Italian version of the Pittsburgh sleep quality index (PSQI). Neurol Sci 2013;34:511–9. https://doi.org/10.1007/s10072-012-1085-y.
[47] Palagini L, Manni R. Misurare il sonno. Torino: Minerva Medica; 2016.
[48] Nicassio PM, Mendlowitz DR, Fussell JJ, et al. The phenomenology of the pre-sleep state: the development of the pre-sleep arousal scale. Behav Res Ther 1985;23:263–71.
[49] Puzino K, Amatrudo G, Sullivan A, et al. Clinical significance and cut-off scores for the pre-sleep arousal scale in chronic insomnia disorder: a replication in a clinical sample. Behav Sleep Med 2020;18(6):705–18. https://doi.org/10.1080/15402002.2019.1669604.
[50] Natale V. Validazione di una scala ridotta di mattutinità (r-MEQ). Boll Psicol Appl 1999;229:19–26.
[51] Gualano MR, Lo Moro G, Voglino G, et al. Effects of Covid-19 lockdown on mental health and sleep disturbances in Italy. Int J Environ Res Publ Health 2020;17(13):4779. https://doi.org/10.3390/ijerph17134779.
[52] Mazza C, Ricci E, Biondi S, et al. A nationwide survey of psychological distress among Italian people during the COVID-19 pandemic: immediate psychological responses and associated factors. Int J Environ Res Publ Health 2020;17:3165. https://doi.org/10.3390/ijerph17093165.
[53] Innocenti P, Puzella A, Mogavero MP, et al. Letter to editor: CoVID-19 pandemic and sleep disorders-a web survey in Italy. Neurol Sci 2020;41(8):2021–2. https://doi.org/10.1007/s10072-020-04523-1.
[54] Uccella S, De Grandis E, De Carli F, et al. Impact of the COVID-19 outbreak on the behavior of families in Italy: a focus on children and adolescents. Front Public Health 2021;9:608358. https://doi.org/10.3389/fpubh.2021.608358.
[55] Fortunato VJ, Harsh J. Stress and sleep quality: the moderating role of negative affectivity. Pers Indiv Differ 2006;41:825–36.
[56] Altena E, Micoulaud-Franchi JA, Geoffroy PA, et al. The bidirectional relation between emotional reactivity and sleep: from disruption to recovery. Behav Neurosci 2016;130:336–50.
[57] Kashani M, Eliasson A, Vernalis M. Perceived stress correlates with disturbed sleep: a link connecting stress and cardiovascular disease. Stress 2012;15:45–51.
[58] Jansson M, Linton SJ. Psychosocial work stressors in the development and maintenance of insomnia: a prospective study. J Occup Health Psychol 2006;11:241–8.
[59] Vahtera J, Kivimaki M, Hublin C, et al. Liability to anxiety and severe life events as predictors of new-onset sleep disturbances. Sleep 2007;30:1537–46.
[60] Richards A, Kanady JC, Neylan TC. Sleep disturbance in PTSD and other anxiety-related disorders: an updated review of clinical features, physiological characteristics, and psychological and neurobiological mechanisms. Neuropsychopharmacology 2020;45(1):55–73. https://doi.org/10.1038/s41386-019-0486-5.
[61] Hall M, Vasko R, Buysse D, et al. Acute stress affects heart rate variability during sleep. Psychosom Med 2004;66:56–62.
[62] Haynes SN, Adams A, Franzen M. The effects of presleep stress on sleep-onset insomnia. J Abnorm Psychol 1981;90:601–6.
[63] Wuyts J, De Valck E, Vandekerckhove M, et al. The influence of pre-sleep cognitive arousal on sleep onset processes. Int J Psychophysiol 2012;83:8–15.
[64] Steiger A, Pawlowski M. Depression and sleep. Int J Mol Sci 2019;20:607. https://doi.org/10.3390/ijms20030607.
[65] Jansson-Fröjmark M, Norell-Clarke A. Psychometric properties of the Pre-Sleep Arousal Scale in a large community sample. J Psychosom Res 2012;72(2):103–10. https://doi.org/10.1016/j.jpsychores.2011.10.005.
[66] Liu N, Zhang F, Wei C, et al. Prevalence and predictors of PTSS during COVID-19 outbreak in China hardest-hit areas: gender differences matter. Psychiatr Res 2020;287:112921.
[67] Zhang F, Shang Z, Ma H, et al. Epidemic area contact history and sleep quality associated with posttraumatic stress symptoms in the first phase of COVID-19 outbreak in China. Sci Rep 2020;10(1):22463. https://doi.org/10.1038/s41598-020-80649-8.
[68] Duran S, Erkin Ö. Psychologic distress and sleep quality among adults in Turkey during the COVID-19 pandemic. Prog Neuropsychopharmacol Biol Psychiatry 2021;107:110254. https://doi.org/10.1016/j.pnpbp.2021.110254.
[69] Cellini N, Conte F, De Rosa O, et al. Changes in sleep timing and subjective sleep quality during the COVID-19 lockdown in Italy and Belgium: age, gender and working status as modulating factors. Sleep Med 2021a;77:112–9. https://doi.org/10.1016/j.sleep.2020.11.027.
[70] Wang W, Song W, Xia Z, et al. Sleep disturbance and psychological profiles of medical staff and non-medical staff during the early outbreak of COVID-19 in Hubei Province, China. Front Psychiatr 2020;11:733. https://doi.org/10.3389/fpsyt.2020.00733.
[71] Adan A, Archer SN, Hidalgo MP, et al. Circadian typology: a comprehensive review. Chronobiol Int 2012;29(9):1153–75. https://doi.org/10.3109/07420528.2012.719971.
[72] Barclay NL, Eley TC, Buysse DJ, et al. Diurnal preference and sleep quality: same genes? A study of young adult twins. Chronobiol Int 2010;27(2):278–96.
[73] Ong JC, Huang JS, Kuo TF, et al. Characteristics of insomniacs with self-reported morning and evening chronotypes. J Clin Sleep Med 2007;3(3):289–94.
[74] Taillard J, Philip P, Bioulac B. Morningness/eveningness and the need for sleep. J Sleep Res 1999;8(4):291–5.
[75] Selvi Y, Kandeger A, Boysan M, et al. The effects of individual biological rhythm differences on sleep quality, daytime sleepiness, and dissociative experiences. Psychiatr Res 2017;256:243–8. https://doi.org/10.1016/j.psychres.2017.06.059.
[76] DeYoung CG, Hasher L, Djikic M, et al. Morning people are stable people: circadian rhythm and the higher-order factors of the Big Five. Pers Indiv Differ 2007;43:267–76.
[77] Cavallera GM, Giudici S. Morningness and eveningness personality: a survey in literature from 1995 up till 2006. Pers Indiv Differ 2008;44:3–21.
[78] Tankova I, Adan A, Buela-Casals G. Circadian typology and individual differences. A review. Pers Indiv Differ 1994;16:671–84.
[79] Drennan MD, Klauber MR, Kripke DF, et al. The effects of depression and age on the Horne–Ostberg morningness–eveningness score. J Affect Disord 1991;23:93–8.
[80] Roeser K, Obergfell F, Meule A, et al. Of larks and hearts–morningness/eveningness, heart rate variability and cardiovascular stress response at different times of day. Physiol Behav 2012;106(2):151–7. https://doi.org/10.1016/j.physbeh.2012.01.023.
[81] Okbay A, Baselmans BML, De Neve J-E, et al. Genetic variants associated with subjective well-being, depressive symptoms, and neuroticism identified through genome-wide analyses. Nat Genet 2016;48(6):624–33.
[82] Salfi F, Amicucci G, Corigliano D, et al. Changes of evening exposure to electronic devices during the COVID-19 lockdown affect the time course of sleep disturbances. Sleep 2021:zsab080. https://doi.org/10.1093/sleep/zsab080.
[83] Huang Y, Zhao N. Generalized anxiety disorder, depressive symptoms and sleep quality during COVID-19 epidemic in China: a web-based cross-sectional survey. Psychiatr Res 2020;288:112954. https://doi.org/10.1016/j.psychres.2020.112954.
[84] Yuan S, Liao Z, Huang H, et al. Comparison of the indicators of psychological stress in the population of Hubei Province and non-endemic Provinces in China during two weeks during the coronavirus disease 2019 (COVID-19) outbreak in February 2020. Med Sci Mon Int Med J Exp Clin Res 2020;26:e923767. https://doi.org/10.12659/MSM.923767.
[85] Salfi F, Lauriola M, Amicucci G, 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.
[86] Zhang W, Wing YK. Sex differences in insomnia: a metaanalysis. Sleep 2006;29:85–93.
[87] Hagen EW, Friedman EM, Hale M, et al. Severity of stressfulness of major life events and insomnia symptoms in women and men. J Sleep Sleep Dis Res 2012;35(Abstract Supplement):A238.
[88] Kelly MM, Tyrka AR, Anderson GM, et al. Sex differences in emotional and physiological responses to the trier social stress test. J Behav Ther Exp Psychiatr 2008;39(1):87–98.
[89] Thomsen DK, Mehlsen MY, Viidik A, et al. Age and gender differences in negative affect—is there a role for emotion regulation? Pers Indiv Differ 2005;38(8):1935–46.
[90] Chen HC, Lin CM, Lee MB, et al. The relationship between pre-sleep arousal and spontaneous arousals from sleep in subjects referred for diagnostic polysomnograms. J Chin Med Assoc 2011;74(2):81–6. https://doi.org/10.1016/j.jcma.2011.01.016.
[91] Vochem J, Strobel C, Maier L, et al. Pre-sleep arousal scale (PSAS) and the time monitoring behavior-10 scale (TMB-10) in good sleepers and patients with insomnia. Sleep Med 2019;56:98–103. https://doi.org/10.1016/j.sleep.2019.01.022.
[92] Shoji KD, McCrae CS, Dautovich ND. Age differences in the role of cognitive versus somatic arousal in sleep outcomes. Behav Sleep Med 2014;12(4):257–71. https://doi.org/10.1080/15402002.2013.801344.
[93] Hertenstein E, Nissen C, Riemann D, et al. The exploratory power of sleep effort, dysfunctional beliefs and arousal for insomnia severity and polysomnography-determined sleep. J Sleep Res 2015;24(4):399–406. https://doi.org/10.1111/jsr.12293.
[94] Exelmans L, Van den Bulck J. Binge viewing, sleep, and the role of pre-sleep arousal. J Clin Sleep Med 2017;13(8):1001–8. https://doi.org/10.5664/jcsm.6704.
[95] Puzino K, Frye SS, LaGrotte CA, et al. Am I (hyper)aroused or anxious? Clinical significance of pre-sleep somatic arousal in young adults. J Sleep Res 2019 2019;28(4):e12829. https://doi.org/10.1111/jsr.12829.
[96] Schneider MN, Denis D, Buysse DJ, et al. Associations between pre-sleep arousal and insomnia symptoms in early adulthood: a twin and sibling study. Sleep 2019;42(5):zsz029. https://doi.org/10.1093/sleep/zsz029.
[97] Liu Z, Tang H, Jin Q, et al. Sleep of preschoolers during the coronavirus disease 2019 (COVID-19) outbreak. J Sleep Res 2020;30(1):e13142. https://doi.org/10.1111/jsr.13142.

[98] Moore SA, Faulkner G, Rhodes RE, et al. Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: a national survey. Int J Behav Nutr Phys Activ 2020;17:85. https://doi.org/10.1186/s12966-020-00987-8.

[99] Pietrobelli A, Pecoraro L, Ferruzzi A, et al. Effects of COVID-19 lockdown on lifestyle behaviors in children with obesity living in Verona, Italy: a longitudinal study. Obesity 2020;28:1382–5. https://doi.org/10.1002/oby.22861.

[100] Di Giorgio E, Di Riso D, Mioni G, et al. The interplay between mothers' and children behavioral and psychological factors during COVID-19: an Italian study. Eur Child Adolesc Psychiatr 2020. https://doi.org/10.1007/s00787-020-01631-3.

[101] Cellini N, Di Giorgio E, Mioni G, et al. Sleep and psychological difficulties in Italian school-age children during COVID-19 lockdown. J Pediatr Psychol 2021b;46(2):153–67. https://doi.org/10.1093/jpepsy/jsab003.

[102] Bruni O, Malorgio E, Doria M, et al. Changes in sleep patterns and disturbances in children and adolescents in Italy during the COVID-19 outbreak. Sleep Med 2021;S1389–9457(21):94–100. https://doi.org/10.1016/j.sleep.2021.02.003.

[103] Zreik G, Asraf K, Haimov I, et al. Maternal perceptions of sleep problems among children and mothers during the coronavirus disease 2019 (COVID-19) pandemic in Israel. J Sleep Res 2021;30(1):e13201. https://doi.org/10.1111/jsr.13201.

[104] Garde AH, Albertsen K, Persson R, et al. Bi-directional associations between psychological arousal, cortisol, and sleep. Behav Sleep Med 2011;10:28–40.

[105] Li Y, Qin Q, Sun Q, et al. Insomnia and psychological reactions during the COVID-19 outbreak in China. J Clin Sleep Med 2020;16(8):1417–8. https://doi.org/10.5664/jcsm.8524.

[106] Wright Jr KP, Linton SK, Withrow D, et al. Sleep in university students prior to and during COVID-19 Stay-at-Home orders. Curr Biol 2020;30(14):R797–8. https://doi.org/10.1016/j.cub.2020.06.022.

[107] Mander BA, Winer JR, Walker MP. Sleep and human aging. Neuron 2017;94(1):19–36. https://doi.org/10.1016/j.neuron.2017.02.004.

[108] Kocevska D, Blanken TF, Van Someren EJW, et al. 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.

[109] Zhang C, Yang L, Liu S, et al. One-week self-guided internet cognitive behavioral treatments for insomnia in adults with situational insomnia during the COVID-19 outbreak. Front Neurosci 2021;14:622749. https://doi.org/10.3389/fnins.2020.622749.