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

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**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 (i.e., 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 (i.e., 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.

**Keywords**

COVID-19 pandemic, sleep quality, pre-sleep arousal, stress, depression

## 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 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 (i.e., 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 (i.e., 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). 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 ≥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 (i.e., 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 (i.e., 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) [38] was used to assess event-related traumatic stress. This scale was first developed by Horowitz [39]. It is a self-reported questionnaire composed by 15 items. Total score ≥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. Subsequently, we controlled the participants' compliance, confirming that all reported stressful events were pandemic-related. In the current sample, the Cronbach's alpha was 0.86.

*Depressive symptoms:* the Beck Depression Inventory-II (BDI-II; [40]) 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; [41]) was administered to investigate sleep quality. It is a self-reported questionnaire consisting of 19 items. The results are about partial scores in 7 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 [42]) has been used to assess pre-sleep arousal [43]. It is a self-reported questionnaire consisting of 16 items for evaluating somatic (8 items) and cognitive (8 items) arousal experienced at bedtime while attempting to fall asleep. We adopted pathological cut-off scores of ≥14 and ≥20 for the somatic and cognitive subscale, respectively [44]. 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; [45]). 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 (i.e., 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 (i.e., lockdown vs. pre-lockdown difference) in hours-per-day spent in home, lockdown-related changes (i.e., 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 ≥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 (i.e., 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 (Figure 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.

*Please insert Figure 1 and Table 1 about here*

### *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 (i.e., 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 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 (Figure 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.

*Please insert Figure 2 about here*

### *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 (Figure 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 (i.e., 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 (Figure 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.

*Please insert Figure 3 and 4 about here*

## 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 [5,10,11,15,22,30,37,46-49], 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.

### *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 [50-54] and a large percentage of subjects with post-traumatic stress disorder (PTSD) suffers from sleep problems [55]. Experimentally induced stress is followed by greater arousal at bedtime, inducing poorer sleep in both good and poor sleepers [56-58]. 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 [59] and pre-sleep arousal [43,60].

The association between sleep problems and different stress-related measures during the COVID-19 pandemic has been widely documented [5,11,29,30,37,61-64]. Also, during the pandemic, depressive symptoms have been observed in association with insomnia severity [15], low sleep quality [5,29,30,65], 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 [66-70]. Moreover, eveningness is associated with higher susceptibility to stress [71], reduced emotional stability [72,73], depression [74] and greater physiological arousal at rest and during stress conditions [75]. A genetic study in 105,739 UK Biobank participants also demonstrated that eveningness is causally associated with lower subjective wellbeing [76]. 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 [77] 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 [78] 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 [11,46,79], depression [16,79], 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 [80], several studies found no relationship between age and sleep disturbance/poor sleep quality [11,16,30,46,79]. 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 [11,30,46,62,64,77,81]. It is well-known that insomnia is more frequent in women [82], which also report higher event-related stress rates [83], and results more emotionally reactive to stress and negative stimuli [84,85]. Chen and co-workers [86] found that women had greater somatic pre-sleep arousal than men in a group of patients with suspected sleep-disordered breathing. Vochem and coworkers [87] 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 [11,31,63]. 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 [44,88-91]. 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 [92]. Interestingly, the studies of Puzino and coworkers [44,91] 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 [49]. One Turkish study found that subjects with children showed higher psychological distress during the pandemic than those without children [63]. Also, children’s sleep has been found to be strongly affected by the pandemic [49,93-98], and a strong correlation between caregivers’ discomfort and their children’s malaise has been observed [49].

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 [99]. Moreover, mothers showing higher COVID-19 anxiety had greater insomnia symptoms and children exhibiting lower sleep quality [99]. 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 [96]. 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 [97] 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 [97]. 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*

These results suggest that, beyond the strongest association with the emotional status (i.e., stress, depression), specific environmental conditions and sociodemographic variables can differentially affect specific sleep domains (i.e., sleep quality, cognitive, and somatic pre-sleep arousal) during the pandemic. 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 [100].

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 [9,12,101-103] 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.

## 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. 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 (e.g., [5,11,22,23]). The cross-sectional nature of the study limits the possible interpretation in terms of causal effects, highlighting the need for longitudinal evaluations. Finally, 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 [104]. 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.

## 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]. 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 [105]. Prompt interventions to modulate pre-sleep arousal and sleep quality during the pandemic are needed.

**Data availability**

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

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## Figure Legend

**Figure 1.** Description of the participants' enrolment.

**Figure 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.

**Figure 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.

**Figure 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.

Table 1

**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.

Figure 1



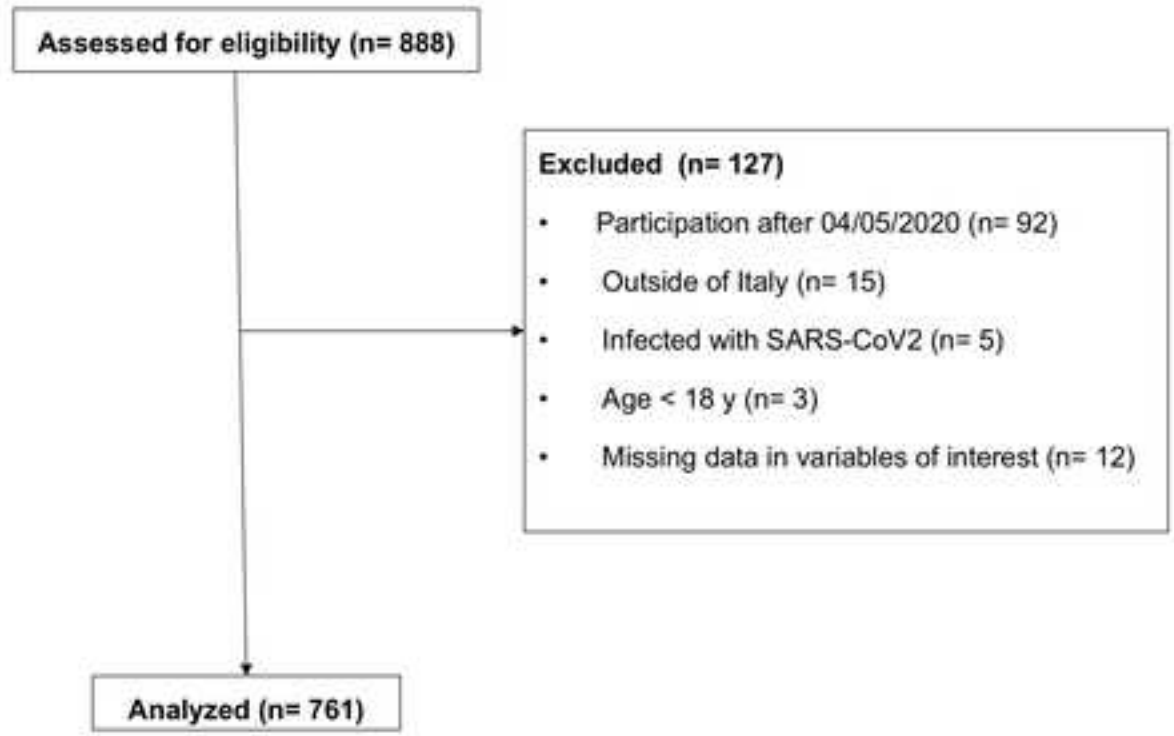

Assessed for eligibility (n= 888)
Excluded (n= 127)
• Participation after 04/05/2020 (n= 92)
• Outside of Italy (n= 15)
• Infected with SARS-CoV2 (n= 5)
• Age < 18 y (n= 3)
• Missing data in variables of interest (n= 12)
Analyzed (n= 761)

Figure 2 Click here to access/download;Figure;Figure 2.tif

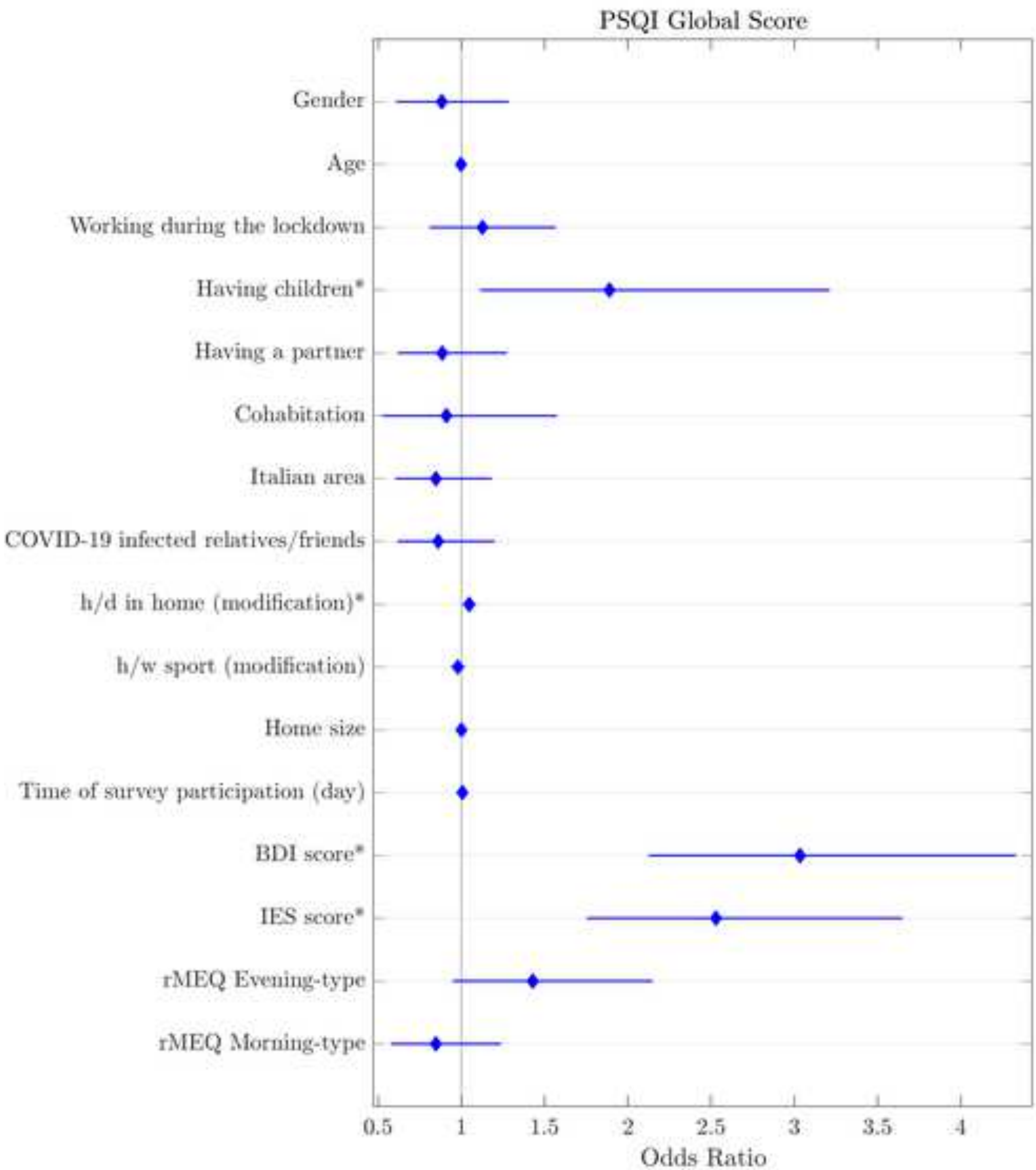


Figure 3

Click here to access/download;Figure;Figure 3.tif

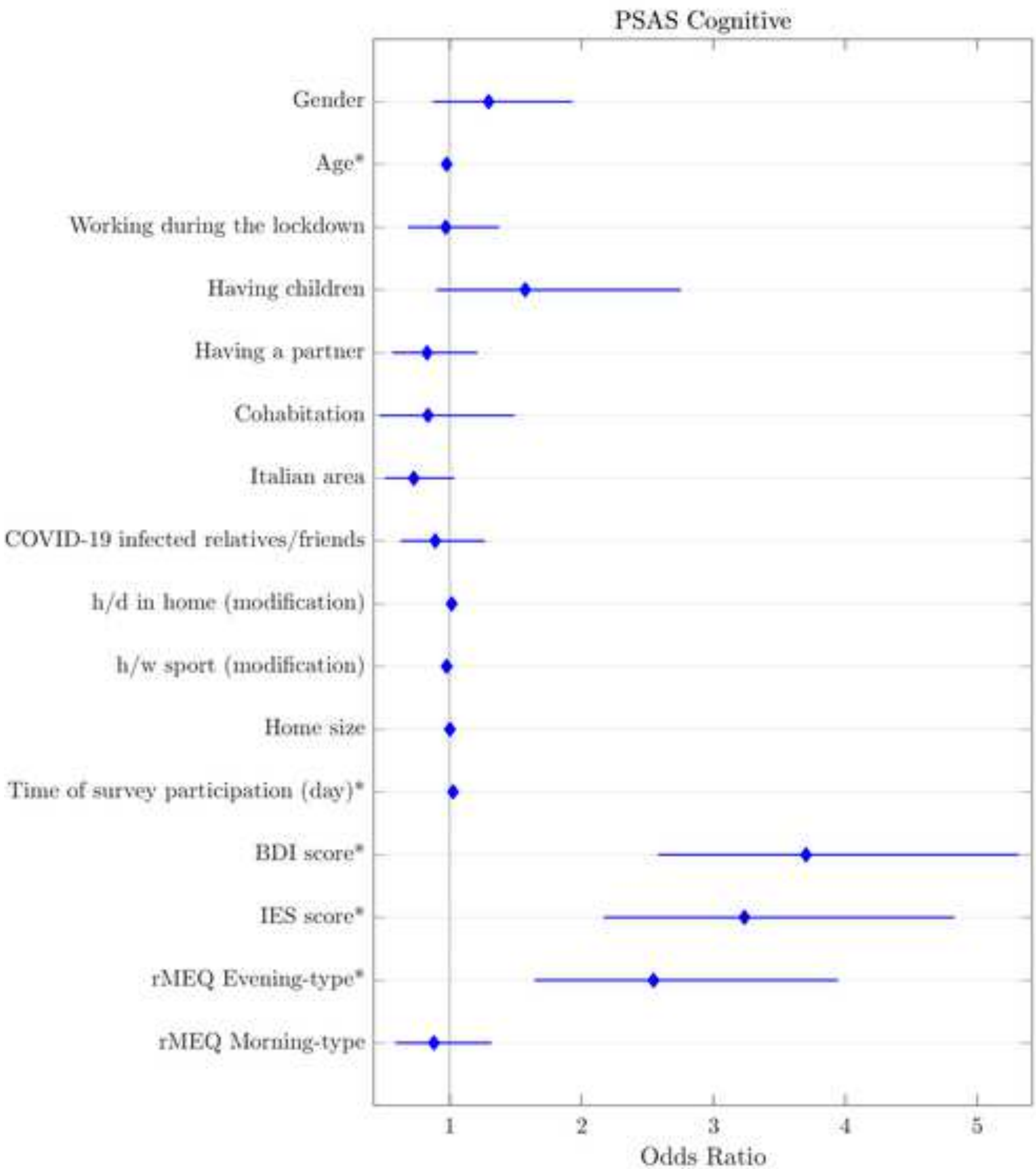
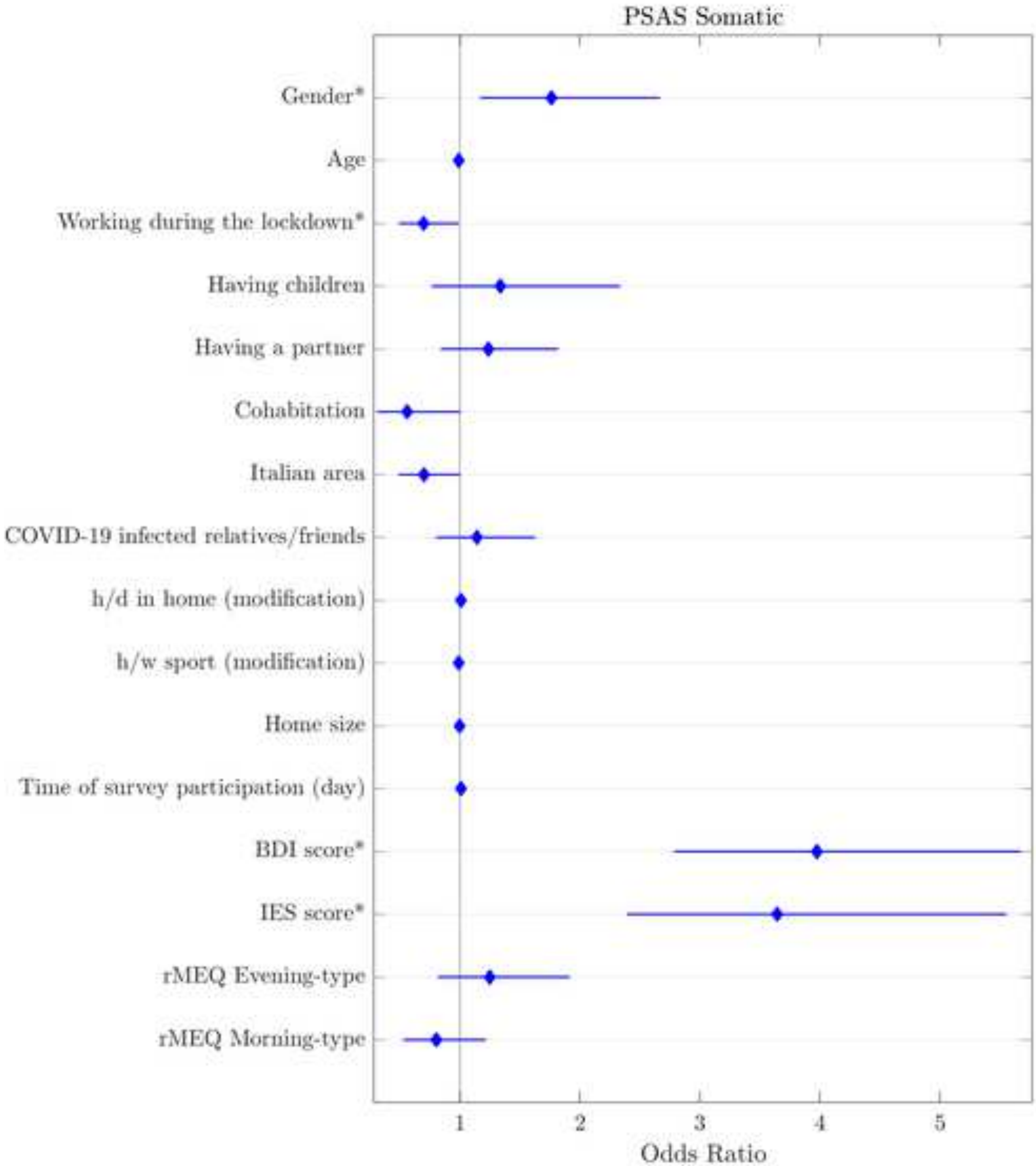


Figure 4





PSAS Somatic
Gender*
Age
Working during the lockdown*
Having children
Having a partner
Cohabitation
Italian area
COVID-19 infected relatives/friends
h/d in home (modification)
h/w sport (modification)
Home size
Time of survey participation (day)
BDI score*
IES score*
rMEQ Evening-type
rMEQ Morning-type
1
2
3
4
5
Odds Ratio

Supplementary Figure Legend

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Supplementary Material.docx

Supplementary Figure 1

**CRedIT authorship contribution statement**

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