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ORIGINAL ARTICLE

Changes of evening exposure to electronic devices during the COVID-19 lockdown affect the time course of sleep disturbances

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Abstract

Study Objectives: During the coronavirus disease 2019 (COVID-19) lockdown, there was a worldwide increase in electronic devices' daily usage. Prolonged exposure to backlit screens before sleep influences the circadian system leading to negative consequences on sleep health. We investigated the relationship between changes in evening screen exposure and the time course of sleep disturbances during the home confinement period due to COVID-19.

Methods: 2,123 Italians (mean age ± standard deviation, 33.1 ± 11.6) were tested longitudinally during the third and the seventh week of lockdown. The web-based survey evaluated sleep quality and insomnia symptoms through the Pittsburgh Sleep Quality Index and the Insomnia Severity Index. The second assessment survey inquired about intervening changes in backlit screen exposure in the two hours before falling asleep.

Results: Participants who increased electronic device usage showed decreased sleep quality, exacerbated insomnia symptoms, reduced sleep duration, prolonged sleep onset latency, and delayed bedtime and rising time. In this subgroup, the prevalence of poor sleepers and individuals reporting moderate/severe insomnia symptoms increased. Conversely, respondents reporting decreased screen exposure exhibited improved sleep quality and insomnia symptoms. In this subgroup, the prevalence of poor sleepers and moderate/severe insomniacs decreased. Respondents preserving screen time habits did not show variations of the sleep parameters.

Conclusions: Our investigation demonstrated a strong relationship between modifications of evening electronic device usage and time course of sleep disturbances during the lockdown period. Monitoring the potential impact of excessive evening exposure to backlit screens on sleep health is recommendable during the current period of restraining measures due to COVID-19.

Statement of Significance

The present investigation is the first to provide insights on the relationship between changes in evening electronic device usage and time course of sleep disturbances during the coronavirus disease 2019 (COVID-19) lockdown. We demonstrated a strong association between screen time modifications in the hours before falling asleep, development and exacerbation of sleep disturbances, and changes of sleep/wake patterns during home confinement due to the COVID-19 pandemic. To date, hundreds of millions of people are subjected to restraining measures worldwide. Our findings may have large scale implications, considering the inevitable increase in the use of digital devices during the current period of limited physical social interactions. Avoiding evening overexposure to electronic screens may help preserve sleep health during the pandemic emergency.

Key words: COVID-19; lockdown; sleep health; insomnia; electronic devices; evening screen exposure

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Introduction

The rapid worldwide spread of the coronavirus disease 2019 (COVID-19) pandemic marked the first months of 2020. During this unprecedented situation, governments across the globe implemented extraordinary measures to reduce the spread of contagion and the pressure on the healthcare systems. From 9 March to 4 May 2020 a total lockdown was imposed in Italy, involving large-scale closure of most work activities, social distancing, and home-based quarantine for the general population. Home confinement measures had a substantial negative impact on global mental health and psychological well-being [1, 2]. The considerable impairment of the daily routine had consistent repercussions on sleep health and circadian rhythms, as documented by several studies [3–6]. However, evidence on the time course of sleep disturbances during the extended period of restraining measures is scarce [7, 8].

The forced social isolation and the limitations of outdoor activities led to a worldwide increase in web-based social communication. In the countries hit hardest by the virus, the total messaging and the time spent on social network increased more than 50%, while the time in video calling increased tenfold [9]. In Italy, during the lockdown, the daily internet traffic volume almost doubled compared to the previous year [10]. Most people spent more time on smartphones and computers [11, 12], and, for example, in the UK adults spent 40% of their day facing a screen during confinement.[13] Electronic devices daily usage increased to compensate for the limited social interactions, fill up free time, and ward off boredom. Furthermore, working from home has become the norm for millions of workers worldwide, and 40% of those currently working in the European Union began to telework full-time due to the pandemic [14]. The implementation of these habits may have helped to cope with the challenging and stressful isolation period. Nevertheless, the increase of screen exposure in the hours before bedtime could have determined adverse consequences on sleep health. Epidemiological and cross-sectional studies indeed showed a strong relationship between the use of electronic devices after sundown and alterations of sleep patterns [15–22]. Firstly, the usage of electronic devices may displace sleep time [23]. Moreover, screen-based activities are related to digital engagement, and the activity type plays a role in the digital media effects on sleep [24]. The screen-mediated contents could be emotionally or psychologically arousing, making it more difficult for individuals to relax before bedtime and, thus, interfering with sleep [23–25]. In particular, portable mobile and media devices allow real-time interactions and hence continuous stimulation [26]. Finally, sleep rhythms are intimately linked with the ambient light, which represents a crucial regulator of the biological clock [27, 28]. The evening exposure to short-wavelength-enriched light emitted from most screens of modern electronic devices (computer, smartphone, tablet, television) can have alerting effects suppressing melatonin release. This assumption has been confirmed by investigations that experimentally manipulated the evening light exposure of tablet [29], eReader [30], and computer screens [31, 32], showing a concomitant decrease of objective and self-reported sleepiness, higher sleep onset latency, and altered sleep architecture.

Therefore, light per se and the stimulating content of electronic devices during the hours preceding habitual bedtime may interfere with sleep patterns intervening on biological and cognitive mechanisms simultaneously [33].

Difficulties in falling asleep (e.g. in insomnia), on the other hand, may lead to longer time spent engaging with screens in the evening hours, establishing a vicious circle.

Based on this evidence, the present study aimed to shed light on the relationship between the longitudinal changes of sleep disturbances between the third (March 25–28, 2020) and the seventh week (April 21–27, 2020) of home confinement in Italy and the retrospectively reported modifications of the exposure to electronic devices before falling asleep during the same lockdown period. We hypothesized that changes in electronic device usage could be a crucial moderator of the lockdown-related sleep alterations over time. We expected that individuals who increased screen exposure in the two hours before sleep onset should have shown the largest sleep impairments and the most marked alterations of the sleep/wake schedule. On the other hand, subjects who reduced evening screen time should have exhibited a positive time course of sleep disturbances.

Methods

Participants and procedure

The present investigation is part of a larger research project aimed to understand the consequences of COVID-19 lockdown on the Italian population [6, 7, 34]. A total of 7,107 Italian citizens were recruited in a web-based survey through a snowball sampling during the third week of lockdown (March 25–31, 2020). The survey comprised a demographic questionnaire (age, gender, education, occupation, and geographical location), the Pittsburgh Sleep Quality Index [35] (PSQI), the Insomnia Severity Index [36] (ISI), and the reduced version of the Morningness–Eveningness Questionnaire [37] (MEQr), in this order. The PSQI is a validated tool to evaluate sleep quality comprising nineteen questions, from which a total score (range 0–19) is calculated. A score >5 identifies poor sleepers. The ISI is a validated instrument used to assess the severity of insomnia symptoms. The total score ranging between 0 and 21, and a score >14 indicates the presence of moderate/severe clinical insomnia condition. The MEQr is a validated questionnaire, and its total score is used to identify the chronotype (4–10 score: evening-type; 11–18 score: intermediate-type; 19–25 score: morning-type). Subsequently, respondents could decide whether continue the compilation of other three questionnaires (Beck Depression Inventory-second edition, BDI-II [38]; 10-item Perceived Stress Scale, PSS-10 [39]; state-anxiety subscale of the State-Trait Anxiety Inventory, STAI-X1 [40]), with the option to stop after each of them. This feature aimed at ensuring higher reliability of the data collected, avoiding false answers in the last questionnaires. The BDI-II is a validated questionnaire used to assess clinical depression symptoms (range 0–63). The PSS-10 is a 10-item questionnaire evaluating the perceived stress following stressful events (range, 0–40). The STAI-X1 is a well-established 20-item scale measuring state anxiety (range, 1–80). In all these questionnaires, higher scores indicate more severe conditions. We included the assessment of depression, perceived stress, and anxiety because they are closely related to the sleep outcomes in the pre-pandemic [41], and pandemic period [5, 42]. In this view, it is important to isolate the effects of the screen exposure changes from the effects of these psychological dimensions to explain the time course of sleep variables.

After four weeks, the website link of the follow-up survey was provided to the participants via email address/telephone number. A total of 2,701 subjects completed the second assessment in a 7-day period (April 21–27, 2020). From this large follow-up sample, we included in the reported analyses only the 2,123 respondents (mean age ± standard deviation, 33.1 ± 11.6; range, 18–82; 401 men, see Table 1) who completed the first survey during the four days preceding the daylight-saving time (March 25–28, 2020; Survey wave 1). This allowed us to avoid interfering and confounding effects at the baseline measurement due to the summertime beginning (for a review, [43]). During the follow-up survey (Survey wave 2), participants completed the same questionnaires of Survey wave 1. Moreover, they were asked to retrospectively evaluate the changes (increase, maintenance, reduction) from the first assessment in the usage duration of electronic devices (smartphone, computer, tablet, television, eReader) in the 2 h before falling asleep.

At Survey wave 1, a total of 1,783 respondents completed the BDI-II, 1,697 filled in also the PSS-10, and 1,675 completed all the questionnaires, while at Survey wave 2 the number of respondents for the last three optional questionnaires (BDI-II, PSS-10, STAI-X1) was 1,873, 1,811, and 1,789, respectively. The study was approved by the institutional review board of the University of L'Aquila (protocol no. 43066) and carried out according to the principles established by the Declaration of Helsinki. Online informed consent to participate in the whole research was obtained from all the respondents during the first assessment.

Table 1. Sociodemographic composition of the sample participating in both the first and the second measurement (Survey wave 1: March 25–28, 2020; Survey wave 2: April 21–27, 2020)

Gender	
Male	401 (18.9%)
Female	1,722 (81.1%)
Age	
18–30 years	1,263 (59.5%)
31–50 years	598 (28.2%)
>50 years	262 (12.3%)
Education	
Until middle school	31 (1.5%)
High school	686 (32.3%)
Graduated	1,406 (66.2%)
Occupation	
Unemployed	184 (8.7%)
Employed	1,172 (55.2%)
Student	767 (36.1%)
Geographical location	
Northern Italy[a]	767 (36.1%)
Central Italy[b]	593 (27.9%)
Southern Italy[c]	763 (35.9%)
Electronic device usage	
Increased	751 (35.4%)
Unchanged	1,221 (57.5%)
Reduced	151 (7.1%)

[a] Northern Italy: Aosta Valley, Emilia Romagna, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Trentino-Alto Adige, and Veneto.
[b] Central Italy: Lazio, Marche, Tuscany, and Umbria. [c] Southern Italy: Abruzzo, Apulia, Basilicata, Calabria, Campania, Molise, Sardinia, and Sicily.

Data analysis

In order to control for potential selection bias of the follow-up participants, we performed preliminary mixed model analyses comparing the Survey wave 1 questionnaire scores of respondents who participated only to the first assessment and those who attended both the measurements (Survey wave 1 and Survey wave 2). These control analyses did not highlight significant differences (all $p > 0.10$).

According to the purpose of the present study, the main variables were the PSQI and ISI scores. Additionally, from the PSQI questionnaire, we extracted other variables such as total sleep time (TST, min), sleep onset latency (SOL, min), bedtime (BT, hh:mm), and rise time (RT, hh:mm). To evaluate the time course of the sleep dimensions as a function of the reported changes of exposure to electronic devices, all the above variables were submitted to mixed model analyses with a random intercept per participant, accounting for the expected intraindividual variability. The models comprised "Survey wave" (Survey wave 1, Survey wave 2), "Screen exposure" (Increased, Unchanged, Reduced), and their interaction as predictors. Additionally, "Gender" (male, female) was included as a factor, and age as a covariate, to control for putative effects of these demographic variables on the main outcomes of the present study. Subsequently, explorative analyses were carried out, adding to the models the Survey wave 1 and Survey wave 2 scores of MEQr, BDI-II, PSS-10, and STAI-X1 as time-varying covariates. These further analyses aimed to control for the effects of chronotype, depression, stress, and anxiety on sleep measures. Mixed model analyses were performed using the "lme4" R package [44]. Models were fitted using REML, using the Satterthwaite approximation to compute *p*-values. Bonferroni post hoc tests were obtained using the "emmeans" R package [45]. Finally, the validated cut-off scores of PSQI and ISI were used to determine the prevalence of poor sleepers and moderate/severe insomnia condition. Subsequently, McNemar's tests were performed to evaluate the modifications of the prevalence of sleep disturbances between Survey wave 1 and Survey wave 2 in the three groups characterized by different changes of exposure to electronic devices before falling asleep. For all the analyses, statistical significance was set at $p < 0.05$, and all tests were two-tailed.

Results

Relationships between screen exposure and sleep variables

The results of the mixed model analyses on the sleep variables [PSQI and ISI scores, total sleep time (TST), sleep onset latency (SOL), bedtime (BT), rise time (RT)] are reported in Table 2. The analyses did not highlight significant effects of the "Survey wave" factor for all the sleep variables (all $p \geq 0.24$). "Screen exposure" was significant for all the variables (all $p \leq 0.005$). The analyses yielded a significant effect of the interaction between "Survey wave" and "Screen exposure" predictors for all the variables (all $p \leq 0.001$). The "Age" covariate was significant for PSQI, TST, SOL, BT, and RT (all $p \leq 0.03$), and "Gender" was significant for PSQI, ISI, SOL, BT (all $p \leq 0.001$).

Post hoc comparisons between Survey wave 1 and Survey wave 2 (Figures 1 and 2) suggested that participants who reported an increase of electronic device usage before falling asleep also showed a significant increase over time of PSQI (mean change ± standard error, +1.01 ± 0.15; $p < 0.001$) and ISI scores (+1.26 ± 0.21; $p < 0.001$), a reduction of TST (–16.70 ± 3.22 min; $p < 0.001$), a prolongation of SOL (+4.08 ± 1.31 min; $p = 0.03$), and delayed BT (+23.08 ± 3.13 min; $p < 0.001$) and RT (+18.92 ± 2.83 min; $p < 0.001$). On the other hand, participants who reduced the screen exposure showed concurrent decreases of PSQI (–1.00 ± 0.33; $p = 0.04$) and ISI scores (–1.44 ± 0.42; $p = 0.02$), earlier BT (–23.25 ± 6.70 min; $p = 0.009$), and no changes in TST, SOL, and RT ($p = 1.00$, $p = 0.58$, $p = 0.11$; respectively). No differences in all the variables were obtained for the participant who maintained unchanged electronic device use habits (all $p = 1.00$). Although the mean PSQI and ISI changes between the two survey waves for the groups increasing or reducing the exposure to electronic devices could appear small, they proved to have a clinical significance, as emerged in the analyses on the prevalence of poor sleepers and clinical insomniacs (see next section).

At Survey wave 1, there were no differences in PSQI and ISI scores between respondents who later reported an increase or reduction of screen exposure (both $p = 1.00$). Participants maintaining device use habits showed lower PSQI scores at Survey wave 1 than those who increased or reduced the exposure to backlit screens (both $p < 0.001$). ISI scores were lower at Survey wave 1 for subjects who did not change the screen exposure than participants who increased or reduced it ($p < 0.001$, $p = 0.04$; respectively). The three groups did not differ at Survey wave 1 on TST, SOL, BT, and RT (all $p > 0.85$).

Participants who reported an increase of screen exposure also showed higher PSQI and ISI scores at Survey wave 2, and delayed BT and RT compared to the other two groups (all $p < 0.01$), as well as shorter TST and longer SOL compared to the group that did not change the device usage habits (both $p < 0.001$, see Figure 2). No differences for all the variables were obtained at Survey wave 2 between subjects who reduced or maintained the device usage duration before falling asleep (all $p > 0.32$).

Further control analyses confirmed the above-reported pattern of results, controlling for the covariance of age, gender, chronotype, depression, perceived stress, and anxiety. In particular, the interaction between "Survey wave" and "Screen exposure" remained significant for all the variables (PSQI: $F_{2,1605.95} = 17.50$, $p < 0.001$; ISI: $F_{2,1685.08} = 14.20$, $p < 0.001$; TST: $F_{2,1694.81} = 8.37$, $p < 0.001$; SOL: $F_{2,1711.04} = 4.53$, $p = 0.01$; BT: $F_{2,1664.94} = 17.11$, $p < 0.001$; RT: $F_{2,1645.32} = 12.70$, $p < 0.001$), confirming the crucial role of the changes in screen exposure in explaining the time course of the sleep outcomes during the lockdown.

Relationships between screen exposure and sleep disturbance prevalence

McNemar's tests highlighted a significant prevalence increase of poor sleepers (+11.4%) and of moderate/severe insomnia

Table 2. Results (*F* and *p*) of the mixed model analyses on PSQI score (sleep quality), ISI score (insomnia severity symptoms), total sleep time, sleep onset latency, bedtime, and rise time. The models comprised Survey wave (Survey wave 1, Survey wave 2), Screen exposure (Increased, Unchanged, Reduced) as predictors, their interaction, and age and gender (male, female) as covariates

	PSQI score		ISI score		Total sleep time		Sleep onset latency		Bedtime		Rise time	
Predictors and covariates	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Survey wave	0.11	0.75	0.75	0.39	1.37	0.24	0.49	0.49	0.10	0.76	0.14	0.71
Screen exposure	29.57	<0.001	32.51	<0.001	6.74	0.001	6.14	0.002	7.14	<0.001	5.26	0.005
Survey wave* Screen exposure	20.29	<0.001	23.70	<0.001	9.07	<0.001	6.70	0.001	30.11	<0.001	20.63	<0.001
Age	46.64	<0.001	0.95	0.33	247.53	<0.001	4.60	0.03	184.86	<0.001	397.50	<0.001
Gender	16.62	<0.001	11.64	<0.001	0.89	0.35	19.14	<0.001	13.01	<0.001	0.02	0.89

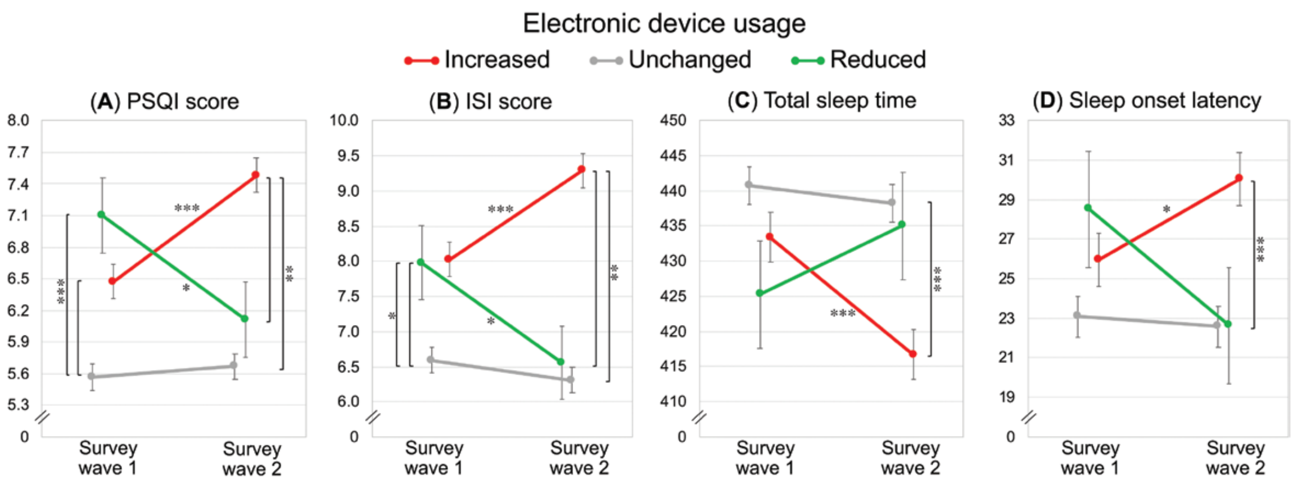

Figure 1. "Survey wave" × "Screen exposure" interaction for PSQI and ISI scores, total sleep time (min), and sleep onset latency (min). Mean ± standard error of the PSQI and ISI scores (A, B), total sleep time (C), and sleep onset latency (D) at the two assessments (Survey wave 1, Survey wave 2) for respondents who declared an increase, preservation, or reduction of the electronic device usage duration before falling asleep. Bonferroni significant post hoc comparisons are reported with asterisks (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

condition (+3.6%) in the group of respondents reporting an increased usage of electronic devices before falling asleep ($\chi^2 = 108.23$, $p < 0.001$, Cohen's $g = 0.21$; $\chi^2 = 149.73$, $p = 0.01$, Cohen's $g = 0.15$; respectively) (Figure 3). On the other hand, there was a significant decrease of poor sleepers (–10.7%) and of moderate/severe insomnia condition (–7.3%) in the group reporting a reduction of the device usage ($\chi^2 = 19.90$, $p = 0.04$, Cohen's $g = 0.18$; $\chi^2 = 12.21$, $p = 0.04$, Cohen's $g = 0.24$; respectively). Finally, in the group of participants who maintained screen habits unchanged there was a reduction of clinical insomnia prevalence (–2.8%; $\chi^2 = 188.51$, $p = 0.002$, Cohen's $g = 0.13$), but not of poor sleepers' prevalence (–2.3%; $\chi^2 = 200.25$, $p = 0.17$, Cohen's $g = 0.04$). According to the standard interpretation of Cohen's g [46], all the variations in the groups of respondents who increased or reduced the screen exposure was of medium extent, while the effect size of the insomnia condition reduction among those who maintained unchanged the use of electronic devices was small.

Discussion

In the present study, we showed a strong relationship between changes in evening screen exposure and time course of sleep parameters during the COVID-19 lockdown.

In line with the initial assumption, individuals declaring increased electronic device usage before falling asleep showed a general sleep impairment over time (from the third to the seventh week of home confinement). This outcome is exemplified by decreased sleep quality, exacerbation of insomnia symptoms, reduced sleep duration, and longer sleep onset latency. Consistently, we found an increased prevalence of poor sleepers and moderate/severe insomnia condition only within this group of respondents. Increased screen exposure was also linked to delayed bedtime and rising time, outlining the delayed sleep phase across the home confinement period. Furthermore, individuals who increased the device usage showed the poorest sleep quality, the most severe insomnia symptoms, the lowest sleep duration, the highest sleep onset latency, and they went

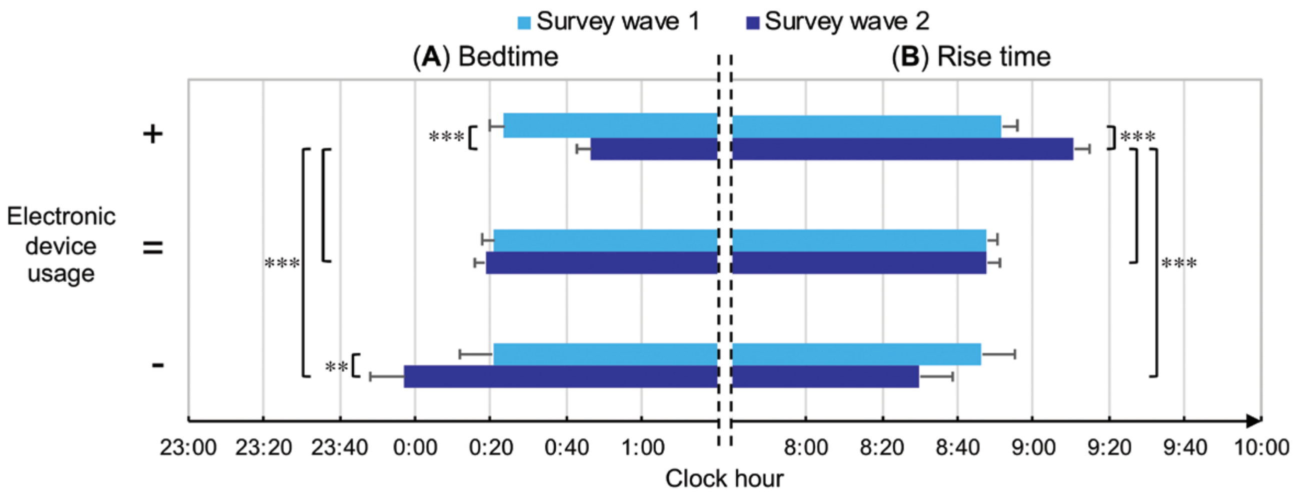

Figure 2. "Survey wave" × "Screen exposure" interaction for bedtime and rise time (hh:mm). Mean ± standard error of the bedtime (A) and rise time (B) at the two assessments (Survey wave 1, Survey wave 2) for participants who declared an increase (+), preservation (=), or reduction (–) of the electronic device usage duration before falling asleep. Bonferroni post hoc results are reported with asterisks (** $p < 0.01$, *** $p < 0.001$).

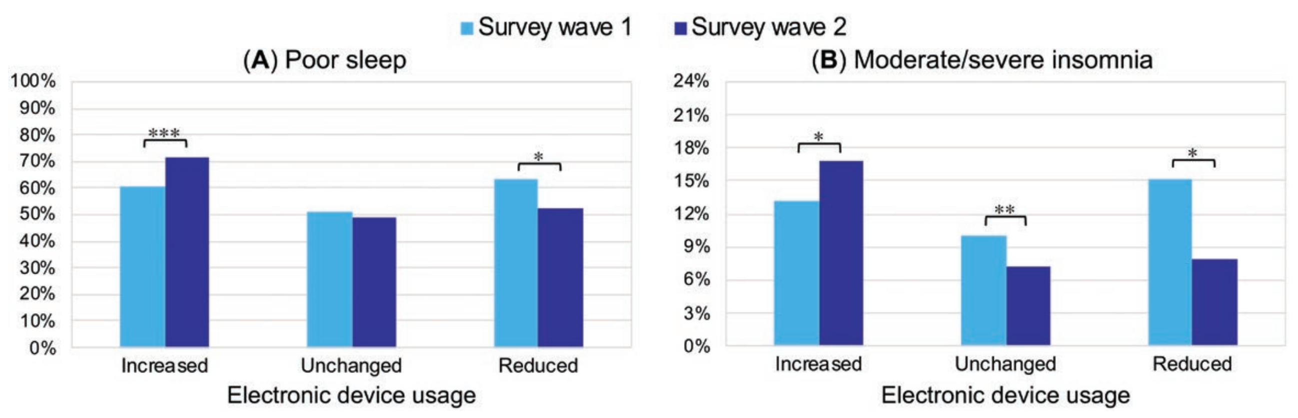

Figure 3. Prevalence of poor sleepers (A) and moderate/severe clinical insomnia condition (B) at the two assessments (Survey wave 1, Survey wave 2) for the respondents who increased, maintained unchanged, or reduced the usage of electronic devices before falling asleep. Significant results of the McNemar's tests are reported with asterisks (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

to bed and woke up later compared to the other participants during the seventh week of lockdown.

In addition, participants reporting decreased evening screen exposure showed the opposite time course of sleep disturbances. They indeed exhibited improved sleep quality and mitigation of insomnia symptoms, which turned into a prevalence reduction of poor sleepers and clinical insomnia condition. This group of respondents went to bed earlier after four weeks of home confinement. Finally, the respondents who maintained unchanged electronic device usage habits did not show any modification in all the examined dimensions, except for a prevalence reduction of moderate/severe insomnia conditions.

Remarkably, we obtained the present findings controlling for the effects of gender and age, and they were confirmed also controlling for the covariance of chronotype, depression, stress, and anxiety. Therefore, our results indicate a direct relationship between evening device usage and time course of sleep disturbances during the home confinement period, independent of other psychological and circadian dimensions.

The pattern of results of our longitudinal investigation is consistent with a large pre-outbreak cross-sectional literature addressing the relationship between sleep and evening electronic device usage. In particular, higher screen time has been associated with reduced sleep duration [15, 47–49], prolongation of sleep onset latency [16–19, 49], later sleep onset and waking up [15, 16, 48], poor sleep quality [15–19], and insomnia symptoms [16, 21, 47].

The COVID-19 pandemic has affected all the world, and home confinement constitutes the most widely used measure to contrast the spread of the contagion. In modern societies, the increase of screen-based device usage could represent an unavoidable consequence of the pandemic-related home confinement periods. Indeed, more than one-third of our sample reported an increase in electronic device usage in the two hours before falling asleep. On the other hand, only a small percentage of the sample (7.1%) reduced the evening screen time between the third and the seventh week of lockdown. This evidence suggests that the reduction of screen time and the associated sleep improvement during a prolonged confinement period were rare, while the opposite situation was quite common. Consequently, our findings have substantial large-scale implications when contextualized to the current unprecedented situation.

Adequate sleep quantity/quality is essential to deal with stressful events [50] and preserve mental health [51, 52], and it plays a crucial role in emotional processing [53, 54] and mood regulation [55]. The increased screen time and its consequences on sleep health may negatively affect psychological well-being increasing anxiety, depression and stress symptoms during the current pandemic period. Indeed, aberrant light exposure and excessive screen time were associated with sleep and mental health problems [56, 57]. Consistently, blocking screen-emitted blue light has proved to be effective in promoting both sleep quality and mood [58, 59] and it was proposed as a useful approach to treat both clinical insomnia [59, 60] and mood disorders [56, 61], although the current literature presents inconsistencies [62].

Finally, sleep and the circadian system support the proper functioning of the immune system [63, 64]. Short sleep duration and poor sleep continuity are associated with increased vulnerability to infectious illness, including higher susceptibility to the common cold and greater symptom reporting [65–67]. The largest vaccination campaign in human history is around the corner, and studies have clearly shown that sleep is an important factor in determining the effectiveness of vaccinations, for example, against influenza viruses [68, 69]. In light of these considerations, the relationship between screen time and sleep outcomes has a broad spectrum of implications, configuring a major public health concern during the COVID-19 outbreak.

The present results were obtained in an Italian sample, but they could be generalized to other modern societies since the putative underlying mechanisms involve a disruption of circadian physiology due to evening light exposure [29–32], increased arousal caused by the stimulating content of the screen-mediated material before bedtime [23–25], and a direct displacement of sleep time [23]. However, we can not infer the causality of this relationship since this is an observational study, and the measurement of screen exposure changes has been retrospectively reported during the second assessment. Notwithstanding that comprehensive literature supported the detrimental effect of electronic devices' evening usage on sleep patterns, we can not exclude reverse causation. Nevertheless, the two interpretations are not mutually exclusive, and a bidirectional model of causation has been suggested [70]. We propose that a vicious circle during the confinement period was established, in which the increased screen exposure before falling asleep negatively impacted the sleep parameters, which in turn supported the overuse of electronic devices after the sunset. Notably, participants who did not change the screen exposure during the examined four weeks of lockdown exhibited the lowest PSQI and ISI scores at the first assessment (Survey wave 1). This outcome could be interpretable as a tendency to maintain unchanged screen habits among individuals with fewer sleep disturbances.

In conclusion, our findings corroborate the assumption that the governments should pursue policies aimed at raising public awareness on healthy sleep behaviors during confinement due to the COVID-19 pandemic, discouraging the excessive use of electronic devices before falling asleep [71, 72]. The evening use of blue-light blocking glasses and the application of a blue wavelength light filter (night shift settings) on the electronic screens should be encouraged to mitigate the well-known detrimental consequences of bright light exposure. In addition, the implementation of psychophysiologically and emotionally arousing screen-based activities such as computer work and surfing the Internet [24], playing videogames [25], and overuse of media to obtain information about COVID-19 [73] should be discouraged before the sleep onset.

To date, the feared risk of a second wave of contagion has become a concrete reality, and hundreds of thousands of people are subjected to home confinement measures worldwide. In light of our results, the above-mentioned interventions focused on sleep hygiene are fundamental to counteract the occurrence and exacerbation of sleep disturbances and foster the general well-being during the period of social distancing and restraining measures due to the COVID-19 pandemic.

Limitations

To the best of our knowledge, the present investigation is the first to provide insights into the relationship between electronic device usage and the time course of sleep disturbances during the COVID-19 lockdown. However, it should be acknowledged that we used a non-probabilistic sampling technique, and the sample comprised a higher prevalence of women and young people. Moreover, under-eighteen years-old individuals were not included. However, the relationship between evening screen time and sleep disturbances was widely shown in adolescents [23, 26, 74]. We hypothesize that our results could be generalizable to younger people. Further research focused on the younger population is necessary as children and adolescents are spending increasingly more time on electronic devices during the pandemic emergency [75]. Additionally, the electronic device category of our survey included a broad set of devices, and we can not discern the relationship between the usage of each device (i.e. smartphone, computer, tablet, television, eReader) and the time course of the sleep outcomes. Finally, in our survey, we did not assess the extent of the screen exposure changes, the use of bright/dim screens, the room lighting, and the implementation of blue-light blocking glasses or blue light filter technology, thus we can not estimate their contribution to the present findings. Further research should be performed accounting for these limitations to disentangle the causal relationship between sleep patterns and the increased digital device usage before sleep onset during the current pandemic period. Future longitudinal investigations should include a detailed day-by-day quantification of screen time for each device (e.g., using daily diaries and/or specific applications), an objective estimation of sleep patterns (e.g., through actigraphy), and an evaluation of the screen-mediated contents as well as the use of blue-light blocking approaches.

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Data Availability Statement

The data underlying this article will be shared on reasonable request to the corresponding author.

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