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Association Between Electronic Device Use at Bedtime and COVID-19 Vaccine-Related Adverse Events During the COVID-19 Pandemic in Korean Adults: A Nationwide Cross-Sectional Population-Based Study

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ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) pandemic has led to heightened mood disturbances linked to increased electronic device use at bedtime (EUB). General anxiety may contribute to an increased likelihood of experiencing nocebo responses, which have been reported to be associated with COVID-19 vaccine-related adverse events (CAEs). However, no related studies have been conducted to examine this association to date.
Methods: We executed a nationwide cross-sectional study to explore these correlations during the pandemic. Using data from the 2022 National Sleep Survey of South Korea, we analyzed the sleep health of 4,000 adults aged 20–69 years between January and February 2022. Shift workers and those with severe sleep disorders were excluded. Participants with EUB more than four days a week were labeled as high frequency EUB, and those reporting CAEs after both vaccine doses were marked as having a presence of CAEs. The survey also included details about anthropometric data, socioeconomic status, and sleep status.
Results: Of the 3,702 participants, 92.6% had received two or more vaccine doses, with 41.2% experiencing CAEs. Furthermore, 73.7% had a high EUB frequency. Factors associated with CAE reporting included younger age, female sex, and high EUB frequency, while heavy alcohol use was found to be less likely to be associated with CAE reporting. Notably, a high EUB frequency was significantly associated with reported CAEs (odds ratio, 1.223; 95% confidence interval, 1.028–1.455; $P = 0.023$).
Conclusion: A nationwide online survey conducted in South Korea during the pandemic found that individuals who engaged in the relatively frequent use of electronic devices during bedtime had worse sleep quality and increased COVID-19-related adverse events compared with those using these devices less frequently. These findings have the potential to enhance our understanding of the impact of the use of electronic devices at bedtime on health.

Keywords: COVID-19 Vaccine; Nocebo Effect; Adverse Events; Smartphone; Epidemiological Study

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Authors Contributions
Conceptualization: Kang KW, Kim M, Kim J, Cho YW. Data curation: Kang KW, Kim M, Kim J, Kim KT, Cho YW. Formal analysis: Kang KW, Cho YW. Investigation: Kang KW. Methodology: Kang KW, Kim KT. Writing - original draft: Kang KW. Writing – review & editing: Cho YW.

INTRODUCTION

The number of smartphone users has increased dramatically over the past few decades, affecting approximately half the global population.[1] Unsurprisingly, South Korea, which has a reputation for embracing new technologies and where most consumers adapt quickly to new trends, is no exception. The smartphone penetration rate among South Koreans is consistently increasing, reaching 92.7% according to a survey conducted in 2021.[2]

Despite the many benefits of smartphones, excessively using them can negatively impact physical and psychological health.[1,3-9] In a cross-sectional study of Chinese junior middle school students, smartphone addiction, defined as using the Smartphone Addiction Scale-Short Version, was found to double the likelihood of developing hypertension.[5] Furthermore, a South Korean survey revealed that university students who used their smartphones for over 4–5 hours daily were at an increased risk for developing depression.[1] A comprehensive review also revealed a consistent relationship between excessive smartphone use and psychological health, including anxiety and depression.[8]

Problematic smartphone use (PSU) refers to excessive mobile phone use that may be related to health issues.[10] With PSU increasing worldwide over time,[11] particularly during the COVID-19 pandemic,[12,13] researchers have focused on its negative health effects. Several studies have found significant links between PSU and psychological and sleep problems.[3,14-16] One mechanism contributing to sleep problems in individuals with PSU is their tendency to engage in electronic device use at bedtime (EUB), which shortens their sleep time.[16,17] Furthermore, sleep problems caused by EUB can affect daily life.[15,18,19] According to a web-based study of Australian adults, engaging in EUB for at least two or three nights per week during the previous seven days was associated with daytime problems.[19] As the COVID-19 pandemic may trigger or worsen PSU,[13] health and sleep problems resulting from EUB could occur.[20]

People may have resorted to PSU and EUB as coping mechanisms during the COVID-19 pandemic, which subsequently affects their sleep and causes emotional disturbances.[1,3,4,7,21-23] Emotional disturbances can be linked to COVID-19 vaccine-related adverse events (CAEs) through the nocebo effect.[24,25] As with its placebo counterpart, the nocebo effect involves the experience of negative symptoms after exposure to an inert substance.[26] Herein, the nocebo included common nonspecific symptoms, such as headache and fatigue after COVID-19 vaccination.[24] A systematic review and meta-analysis of randomized clinical trials of experimental COVID-19 vaccines showed that adverse events were associated with the nocebo effect.[24] Although nocebo-related adverse events were non-serious in this study, side effects can make the vaccination experience unpleasant. Concerns about such side effects are among the most common reasons for vaccine hesitancy.[27] Given the importance of positive attitudes towards vaccines for achieving herd immunity, studies examining factors related to the nocebo effect are crucial in preparing for potential future viral outbreaks.

In today's increasingly digitized society, we cannot ignore the role of electronic devices, particularly smartphones, as lifestyle factors. Their usage, which notably increased during the COVID-19 pandemic, has been associated with mood disturbances.[8,12] Therefore, this may warrant significant consideration in public health strategies for vaccine campaigns. Previous studies have revealed links between mood disturbances and nocebo effects,[28] as well as between mood disturbances and EUB.[29,30] As such, we speculate that there may be

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an association between EUB and CAEs. However, evidence supporting the influence of EUB on CAEs remains scarce. In this nationwide Korean study conducted during the COVID-19 pandemic, we aimed to evaluate the relationship between EUB and CAEs.

METHODS

Participants and procedures

The data for this study were derived from the 2022 National Sleep Survey of South Korea. This survey, initiated by the Epidemiology Committee of the Korean Sleep Research Society, was a nationwide, cross-sectional online survey designed to investigate sleep health among South Koreans aged 20–69 years. It was conducted from January to February 2022 during the COVID-19 pandemic.[31] The survey was carried out by Embrain public company, which maintains a panel of over 1.5 million individuals. Our study selectively included adults from these voluntary panels. With a ± 1.55-point sampling error at a 95% confidence interval, the minimum target population for this study was 3,998. This is because the number of individuals in our target age group in South Korea was 37,133,171 in 2021. We arrived at a final sample of 4,000 individuals, using proportional stratified sampling based on the 2021 Korean Census data for age, sex, occupation, and income.

We excluded shift workers (n = 271) because our focus was to study individuals from the general population who failed to sleep well despite having no actual constraints regarding bedtime. We also excluded participants (n = 27) who reported very short (< 3 hours) or very long sleep durations (> 13 hours), as they were likely to have serious sleep disorders. This study was approved by the Institutional Review Board (IRB) of Keimyung University Hospital (IRB No. DSMC 2021-12-063). All the participants provided written informed consent. Additional details about the study methodology, in accordance with the Checklist for Reporting Results of Internet E-Surveys (CHERRIES), can be found in **Supplementary Table 1**.

Measures

Demographic information

All participants (n = 3,702) provided basic demographic information through a well-established questionnaire. This included information regarding age, sex, presence of sleep partner, employment status, education level, monthly family income, and alcohol and smoking habits. Anthropometric data such as weight and height were also collected.

We collected monthly family income data in units of 1 million won (approximately USD 833), ranging from less than 2 million won (approximately USD 1,666) to over 10 million won (approximately USD 8,330). Income was then categorized as being greater or less than 5 million won following findings of the Basic Living Review Committee of the Korean Ministry of Health and Welfare, whose 2021 determination was that the median income for a family of four was 4.87 million won.

Alcohol consumption was examined in terms of drinking frequency, type of alcohol, and the average amount consumed. At-risk drinking for South Koreans was defined based on the modified guidelines of the National Institute on Alcohol Abuse and Alcoholism.[32] Heavy alcohol consumption was defined as drinking more than eight drinks per week (1 drink = 14 g alcohol) for men under 65 years and more than four drinks per week for men aged 65 years and older. For women, the criteria were half of those for men. Binge drinking was defined as more than three drinks per day for men under 65 years of age and more than two drinks per day for men aged 65 years or older. For women, the criteria were more than two drinks per day for those under 65 years of age and more than one drink per day for those aged 65 years or older.

Smoking status categories were nonsmokers or smokers. Participants who had never smoked were regarded as non-smokers, whereas those who had smoked at least once in their lives were classified as smokers. Body mass index (BMI) was calculated by dividing body weight by the square of height. Obesity was defined as BMI ≥ 25 kg/m^2.

Electronic device use during bedtime and sleep measures

We asked participants about their use of smartphones and tablets during bedtime, as these devices are shown to be significant sources of EUB in a previous study.[33] Participants were asked how many nights a week, on average, they had used their smartphone or tablet at bedtime in the past 7 days. Response options included "not at all," "1–3 nights," "4–6 nights," and "all nights." However, a previous Austrian study showed that technology use at least two or three nights per week was associated with daytime dysfunction and mental health issues.[19] In order to clearly understand the detrimental effects of EUB on health, we decided to categorize the variables into two response options: "less than 4 days" and "more than 4 days" in the past week.

We examined sleep-related variables such as sleep onset latency (SOL), sleep duration, and sleep satisfaction level. Participants rated their sleep satisfaction based on a 5-point Likert scale (1 = very satisfactory, 2 = satisfactory, 3 = moderate, 4 = unsatisfactory, 5 = very unsatisfactory) and their actual sleep time in the past four weeks rather than the time they spent lying in bed. The average sleep duration and latency were calculated using the following formula: [(weekday value × 5) + (weekend value × 2) /7], after asking about sleep duration and latency on weekdays and weekends. Our survey used the Epworth Sleepiness Scale (ESS) to assess daytime sleepiness.

COVID-19 vaccine-related adverse events

Our questionnaire included questions about COVID-19, such as whether the respondent had experienced any CAEs and their vaccination history related to COVID-19. The presence of CAEs was investigated only in participants who received at least two vaccine doses. Our study aimed to encompass various CAEs, regardless of the severity of adverse events following COVID-19 vaccination. Therefore, CAE was measured using the following single questions: "Have you experienced any adverse events from the COVID-19 vaccination?" We only recorded the experience of CAEs and did not analyze their severity.

Statistical analyses

Statistical analyses were performed using SPSS version 22 (IBM Corp., Armonk, NY, USA). Continuous variables were compared using Student's t-test, while categorical variables were compared using Pearson's chi-square test. Multivariate logistic regression analysis was performed to evaluate the factors affecting a higher frequency of EUB and the presence of CAEs. These models were adjusted for covariates that showed P values < 0.1 in the univariate analyses. Results were expressed as odds ratios (OR) with 95% confidence intervals (CI), and statistical significance was defined as a two-tailed P value of < 0.05.

Ethics statement

This study was approved by the IRB of Keimyung University Hospital (IRB No. DSMC 2021-12-063). All participants provided written informed consent for this study.

RESULTS

The mean age of the 3,702 adults surveyed was 44.74 ± 13.36 years, with 1,873 (50.6%) being a woman. Regarding socioeconomic status, participants responded as follows: 2,001 (54.1%) reported sharing a bed with a person such as a partner, spouse, or children; 2,563 (69.2%) reported being currently employed; 2,832 (76.5%) reported having a level of education above university level; and 2,296 (62.0%) reported having a family income of less than 5 million won (**Table 1**). Nearly three-quarters (2,729; 73.7%) were engaged in four or more days of EUB in the past week (**Table 1**).

These individuals were significantly more likely to be younger, female, smokers, and did not share a bed with someone else. These associations remained significant even after adjusting for covariates (**Table 2**).

Association between sleep and electronic device use at bedtime

Table 3 shows that participants with more than four days of EUB per week had shorter mean sleep duration, longer SOL, higher ESS scores, and unsatisfactory self-reported sleep. Despite no significant difference in weekday sleep duration between the groups, those with

Table 1. Clinical information according to the frequency of electronic device usage at bedtime

Variables	Participants (N = 3,702)	Electronic device usage at bedtime		
		≥ 4 days/wk (n = 2,729)	< 4 days/wk (n = 973)	*P* value[a]
Age, yr	44.74 ± 13.36	42.07 ± 13.03	52.21 ± 11.32	< 0.001
Sex				< 0.001
Male	1,829 (49.4)	1,238 (45.4)	591 (60.7)	
Female	1,873 (50.6)	1,491 (54.6)	382 (39.3)	
Presence of a sleep partner				< 0.001
Yes	1,701 (45.9)	1,178 (43.2)	523 (53.8)	
No	2,001 (54.1)	1,551 (56.8)	450 (46.2)	
State of employment				0.724
Unemployed	1,139 (30.8)	844 (30.9)	295 (30.3)	
Employed	2,563 (69.2)	1,885 (69.1)	678 (69.7)	
Education level				0.638
≤ Highschool	870 (23.5)	636 (23.3)	234 (24.0)	
≥ University	2,832 (76.5)	2,093 (76.7)	739 (76.0)	
Monthly family income				0.511
≥ 5 million won	1,406 (38.0)	1,045 (38.3)	361 (37.1)	
< 5 million won	2,296 (62.0)	1,684 (61.7)	612 (62.9)	
Alcohol				
Alcohol consumption, g/wk	49.12 ± 82.78	46.88 ± 79.45	55.42 ± 91.22	0.010
Heavy alcohol drinking	589 (15.9)	422 (15.5)	167 (17.2)	0.213
Binge drinking	1,052 (28.4)	784 (28.7)	268 (27.5)	0.482
Smoking	1,691 (45.7)	1,210 (44.3)	481 (49.4)	0.006
Obesity				
BMI, kg/m^2	23.68 ± 3.68	23.66 ± 3.75	23.73 ± 3.50	0.592
BMI ≥ 25 kg/m^2	1,174 (31.7)	866 (31.7)	308 (31.7)	0.964
COVID vaccination more than 2 times	3,427 (92.6)	2,522 (92.4)	905 (93.0)	0.542

Values are presented as number (%) or mean ± standard deviation.
BMI = body mass index, COVID = coronavirus disease.
[a]Univariate analysis.

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Table 2. Predictors of the high-frequency electronic device use at bedtime

Variables	Electronic device use at bedtime
	≥ 4 days/wk (N = 2,729)
Age	0.935 (0.929–0.941)[a]
Sex	
Male	Reference
Female	2.743 (2.246–3.350)[a]
Presence of a sleep partner	
Yes	Reference
No	1.449 (1.236–1.699)[a]
Alcohol consumption, g/wk	0.999 (0.998–1.000)
Smoking	
Non-smoking	Reference
Smoking	1.568 (1.287–1.910)[a]

Values are presented as odds ratio (95% confidence interval).
The odds ratio and 95% confidence intervals were estimated using a logistic regression model adjusted for age, sex, presence of a sleep partner, weekly alcohol consumption, and smoking status.
[a]$P < 0.001$.

frequent episodes of EUB per week had a longer mean and weekend sleep duration than those with fewer than four days of EUB per week. After adjusting for covariates, high EUB frequency was significantly associated with longer SOL, unsatisfactory sleep, and higher ESS scores.

Participants with a high EUB frequency were less satisfied with their sleep quality. We calculated the ratio of the percentage of participants in each group who reported each level of sleep satisfaction on the Likert scale. For each satisfaction level, the denominator represented the percentage of participants who reported that level of satisfaction among those who reported fewer than four days per week of EUB, whereas the numerator represented the percentage with more than four days per week of EUB among that level. The ratio increased with higher levels of unsatisfactory self-reported sleep reported on the Likert scale (**Fig. 1**). Even after adjusting for covariates, the association between a high EUB frequency and unsatisfactory self-reported sleep persisted (**Table 3**).

Table 3. Association between sleep parameters and the frequency of electronic device use at bedtime

Sleep parameters	Electronic device use at bedtime			Adjusted OR[a]	
	≥ 4 days/wk (n = 2,729)	< 4 days/wk (n = 973)	*P* value	OR (95% CI)	*P* value
Reported sleep duration					
Weekday sleep duration, hr	6.66 ± 1.20	6.62 ± 1.12	0.338	0.945 (0.881–1.014)	0.115
Weekend sleep duration, hr	7.73 ± 1.46	7.47 ± 1.31	< 0.001	1.006 (0.948–1.068)	0.834
Mean sleep duration, hr	6.97 ± 1.13	6.86 ± 1.08	0.010	0.959 (0.891–1.032)	0.268
Reported SOL					
Weekday SOL, min	33.13 ± 28.01	22.40 ± 19.63	< 0.001	1.019 (1.015–1.024)	< 0.001
Weekend SOL, min	37.22 ± 30.49	24.38 ± 21.30	< 0.001	1.019 (0.015–1.023)	< 0.001
Mean SOL, min	34.30 ± 27.56	22.96 ± 19.70	< 0.001	1.020 (0.016–1.025)	< 0.001
Sleep satisfaction			< 0.001		
Very satisfactory	133 (4.9)	68 (7.0)		Reference	
Satisfactory	735 (26.9)	322 (33.1)		1.095 (0.771–1.554)	0.613
Moderate	1,029 (37.7)	381 (39.2)		1.209 (0.857–1.706)	0.280
Unsatisfactory	686 (25.1)	172 (17.7)		1.686 (1.166–2.436)	0.005
Very unsatisfactory	146 (5.3)	30 (3.1)		1.737 (1.020–2.956)	0.042
ESS	6.62 ± 3.55	6.02 ± 3.56	< 0.001	1.043 (1.019–1.067)	< 0.001
Presence of EDS (ESS ≥ 11)	365 (13.4)	104 (10.7)	0.031	1.131 (0.878–1.457)	0.339

Values are presented as number (%) or mean ± standard deviation.
OR = odds ratio, CI = confidence interval, SOL = sleep onset latency, ESS = Epworth Sleepiness Scale, EDS = excessive daytime sleepiness.
[a]Odds ratio and 95% confidence intervals were estimated using a logistic regression model adjusted for age, sex, presence of a sleep partner, weekly alcohol consumption, and smoking status.

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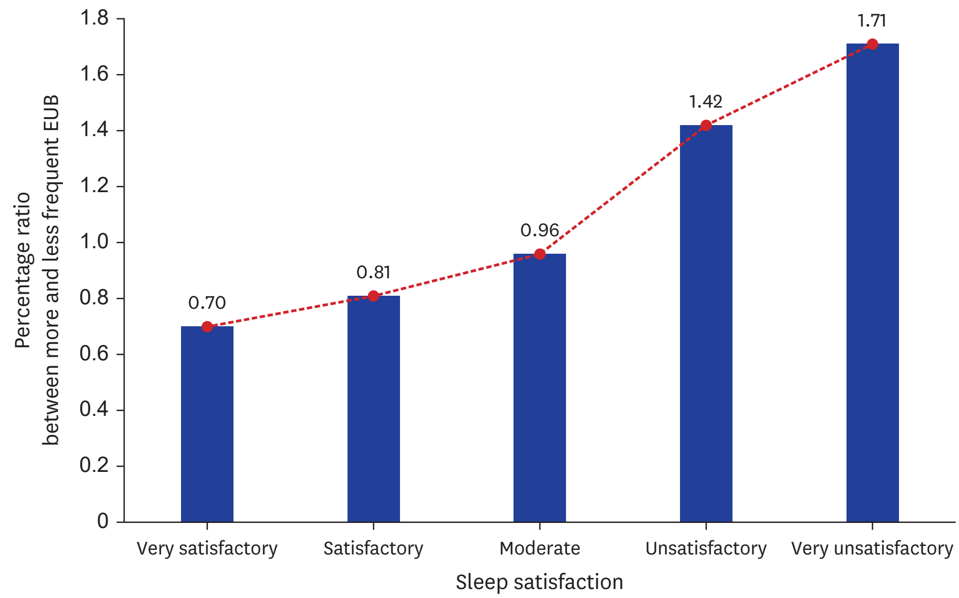

Fig. 1. Differences in self-reported sleep satisfaction according to the frequency of electronic device use at bedtime. The percentage ratio (B/A) of self-reported sleep satisfaction was compared between participants (**A**) who reported using electronic devices at bedtime less frequently (< 4 days/week) and those (**B**) who reported using electronic device at bedtime more frequently (≥ 4 days/week).
EUB = electronic device use at bedtime.

Association between COVID-19 vaccine-related adverse events and electronic device use at bedtime

Of the total participants, 3,427 (92.6%) received two or more vaccine doses, and 1,411 (41.2%) of those individuals experienced CAEs. Among those with CAEs, there was a higher percentage of women (59.1% vs. 43.7%, $P < 0.001$) and younger individuals (42.63 ± 13.08 vs. 46.60 ± 13.35, $P < 0.001$). Moreover, individuals with higher alcohol consumption and binge drinking were less likely to report CAEs (**Table 4**). After adjusting for covariates, the protective effect against CAEs remained significant for higher alcohol consumption, but not for binge drinking (**Table 5**). CAEs were more likely to occur in the group with a high frequency of EUB (**Table 4**).

In multivariate logistic regression analyses, participants with CAEs were more likely to be women and younger, have shorter mean sleep durations, longer mean SOL, and report more unsatisfactory sleep. An EUB frequency exceeding four days per week was significantly associated with CAEs (**Table 5**; OR, 1.223; 95% CI, 1.028–1.455; $P = 0.023$).

DISCUSSION

We investigated the frequency of EUB per week and its association with sleep quality and CAEs. Our findings revealed that frequent EUB (more than four days per week) was associated with self-reported sleep dissatisfaction, longer SOL, and higher ESS scores, consistent with previous studies.[18,19,29,34,35] A systematic review found that bedtime mobile phone use was associated with shorter sleep duration and lower sleep quality, although most studies used self-reported sleep outcomes.[35] However, previous research has mainly focused on adolescents,[15] with a few studies examining the relationship between EUB and sleep in adult populations.[19,29,30,34,35] Most of these adult studies involved young adults in their 20s.[30,35] In adults, the effect of EUB on sleep differs from that in adolescents and young adults. A

Table 4. Association between the presence of adverse events from the COVID-19 vaccines and other variables

Variables	COVID-19 vaccines related adverse events		
	Yes (n = 1,411)	No (n = 2,016)	*P* value
Age, yr	42.63 ± 13.08	46.60 ± 13.35	< 0.001
Female (vs. male)	834 (59.1%)	881 (43.7%)	< 0.001
EUB ≥ 4 days/wk	1,117 (79.2%)	1,405 (69.7%)	< 0.001
Presence of a sleep partner (+)	638 (45.2%)	924 (45.8%)	0.721
Employed (vs. unemployed)	982 (69.6%)	1,432 (71%)	0.365
Alcohol			
Alcohol consumption, g/wk	39.45 ± 64.62	57.11 ± 91.12	< 0.001
Heavy alcohol drinking	181 (12.8%)	368 (18.3%)	< 0.001
Binge drinking	376 (26.6%)	621 (30.8%)	0.008
Smoking (vs. non-smoking)	564 (40.0%)	1,015 (50.3%)	< 0.001
BMI, kg/m^2	23.51 ± 3.82	23.87 ± 3.56	0.005
BMI ≥ 25 kg/m^2	436 (30.9%)	668 (33.1%)	0.168
Sleep satisfaction			< 0.001
Very satisfactory	67 (4.7%)	120 (6.0%)	
Satisfactory	342 (24.2%)	653 (32.4%)	
Moderate	533 (37.8%)	758 (37.6%)	
Unsatisfactory	368 (26.1%)	422 (20.9%)	
Very unsatisfactory	101 (7.2%)	63 (3.1%)	
Mean sleep duration, hr	6.92 ± 1.14	6.93 ± 1.08	0.880
Mean sleep duration ≥ 7 hr	727 (51.5%)	1,002 (49.7%)	0.294
Mean sleep onset latency, min	33.55 ± 27.66	29.60 ± 25.05	< 0.001
Mean sleep onset latency ≥ 30 min	746 (52.9%)	962 (47.7%)	0.003
ESS	6.61 ± 3.60	6.41 ± 3.57	0.102
Presence of EDS (ESS ≥ 11)	194 (13.7%)	252 (12.5%)	0.285

EUB = electronic device use at bedtime, BMI = body mass index, ESS = Epworth sleepiness scales, EDS = excessive daytime sleepiness.

Table 5. Multivariate logistic regression analysis for the presence of adverse events from coronavirus disease 2019 vaccines

Variables	Model 1		Model 2	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Age, yr	0.977 (0.972–0.982)	< 0.001	0.977 (0.971–0.982)	< 0.001
Female (vs. male)	1.761 (1.523–2.035)	< 0.001	1.742 (1.504–2.018)	< 0.001
EUB ≥ 4 days/wk	1.228 (1.032–1.460)	0.020	1.223 (1.028–1.455)	0.023
Alcohol				
Alcohol consumption, g/wk	0.988 (0.997–0.999)	< 0.001	0.998 (0.997–0.999)	< 0.001
Heavy alcohol drinking	0.693 (0.568–0.844)	< 0.001	0.690 (0.566–0.842)	< 0.001
Binge drinking	0.902 (0.764–1.065)	0.222	0.890 (0.754–1.052)	0.172
Smoking (vs. non-smoking)	0.992 (0.839–1.173)	0.925	0.978 (0.826–1.158)	0.795
Body mass index, kg/m^2	0.999 (0.980–1.019)	0.944	0.997 (0.978–1.017)	0.781
Sleep satisfaction		< 0.001		< 0.001
Very satisfactory	Reference		Reference	
Satisfactory	0.924 (0.661–1.290)	0.641	0.924 (0.661–1.290)	0.641
Moderate	1.231 (0.888–1.706)	0.213	1.231 (0.888–1.706)	0.213
Unsatisfactory	1.493 (1.064–2.095)	0.020	1.493 (1.064–2.095)	0.020
Very unsatisfactory	2.829 (1.803–4.439)	< 0.001	2.829 (1.803–4.439)	< 0.001
Mean sleep duration, hr	0.932 (0.874–0.994)	0.031	0.938 (0.880–1.000)	0.051
Mean sleep onset latency, min	1.003 (1.000–1.006)	0.030	1.002 (1.000–1.005)	0.076
ESS	1.018 (0.998–1.038)	0.080	1.015 (0.995–1.035)	0.152

Model 1 was adjusted for age, sex, body mass index, weekly alcohol consumption, smoking status, presence of a sleep partner, state of employment, education level, and monthly family income. Model 2 was adjusted for the variables in Model 1 plus mean sleep duration, mean sleep onset latency, and ESS.
OR = odds ratio, CI = confidence interval, EUB = electronic device use at bedtime, ESS = Epworth sleepiness scales.

cross-sectional study that included 844 Belgian adults (aged 18–94 years) found that bedtime mobile phone use was significantly associated with poor self-reported sleep quality and longer SOL, but not with sleep duration.[34] Our results support this finding, confirming the relationship between EUB frequency and self-reported sleep quality.

Bedtime procrastination (BP), which has been extensively studied in relation to evening technology use, is defined as the act of going to bed later than intended, despite there being no external circumstances that prevent an individual from doing so.[36] The concept of BP is not exactly the same as that of EUB; however, they have similarities. Similar to EUB,[17] BP tied to PSU is significantly associated with anxiety and depression.[9] Interestingly, several studies have found an increase in PSU and BP during the COVID-19 pandemic compared with the pre-pandemic period,[12,13,22,37] such as a Chinese study that showed higher BP scale scores in the post-compared with the pre-COVID-19 outbreak group.[37] Increased anxiety and depression during the COVID-19 pandemic[23,38,39] could have contributed to the rising prevalence of PSU and BP.[9,22,37]

However, as internet-connected devices become smaller, the EUB, another problematic behavior, is also known to be correlated with PSU.[17] It relates to delays in going to sleep due to using electronic devices while already in bed, unlike BP, which focuses on behaviors preceding bedtime.[40] Although a considerable amount of evidence links EUB to physical and mental health symptoms,[18,29,30,34] less research has focused on exploring the effect of EUB on mental health compared to BP. This is primarily because the bedtime procrastination scale used to evaluate BP, which is widely used in related studies so far, does not include the item that can evaluate EUB.[36] However, considering the detrimental effects of mobile phone use in bed after light out on sleep outcome,[34] EUB may be more significant for our health than BP itself.

In our study, we observed a correlation between an increased frequency of EUB and CAEs. This correlation may arise from evidence suggesting that EUB is not only linked with sleep disturbances but also with emotional disturbances.[29,30] Given the documented rise in mood disturbances during the COVID-19 pandemic,[12,13] we theorize that more people might resort to PSU as a maladaptive coping strategy in the face of heightened stress. Consequently, those who frequently experience EUB due to PSU might be more prone to poor sleep quality. Considering the established bidirectional relationship between sleep and mood disturbances,[41,42] emotional disturbances, which might be worsened by poor sleep quality (resulting in turn from frequent EUB), could contribute to the nocebo effect. This effect has been noted as a factor in non-specific CAEs in prior COVID-19 vaccine randomized controlled trials (RCTs) and has tied to emotional disturbances.[24,25] Therefore, we believe that EUB could contribute to an increase in CAEs during the COVID-19 pandemic.

While we do not yet understand the causal relationship between the EUB and emotional disturbances due to the limited number of longitudinal studies, one such study has shown results that contradict our hypothesis. This longitudinal study of 815 young adults found that nighttime smartphone use was associated with higher levels of perceived stress and depressive symptoms at baseline. However, these differences were minor after an average four-month follow-up period.[30] The results should be interpreted with caution, however, because the variables related to nighttime smartphone use were classified into 3 groups (0 Night, 1-3 Nights, > 3 Nights), based on the number of nights with less than six consecutive hours of sleep due to smartphone activities over a 16-week period. Notably, the most frequent disruptions (> 3 Nights) only consisted of 45 participants. Furthermore, the recorded nightly smartphone activity could potentially be underestimated, as it did not consider all relevant activities carried out using the smartphone.[30] Contrarily, previous cross-sectional studies have almost always shown significant associations between EUB and emotional disturbances such as anxiety and depression.[19,29]

The inconsistency in results is likely because the detrimental effect of nighttime smartphone use on mental health is not based on a dose-response relationship, but rather depends on the frequency of smartphone use, which is not yet well-defined. In fact, an Australian study involving a sample of adult participants reported that those who experienced EUB for at least two nights in the past week were significantly more likely to report mood disturbances.[19] Similarly, in our study, EUB for more than four days per week showed a noticeable correlation with CAEs compared to use for fewer than four days (**Supplementary Fig. 1**).

Considering a significant relationship between sleep and mood disturbances,[41,42] it is unsurprising in our study that participants with a higher frequency of EUB were more likely to report unsatisfactory sleep. A study from South Korea echoed our results, revealing that smartphone overuse is tied to depression and delayed bedtimes among university students.[1] Another study further confirmed that, during the COVID-19 pandemic, smartphone overuse correlated with lower sleep quality and delayed sleep phases among Korean middle school students.[43] One potential intervention could be to curtail mobile phone use at bedtime. Supporting this idea, a small-sized RCT found that restricting mobile phone use before bedtime for a period of four weeks enhanced participants' sleep profiles and positive affect.[44] A meta-analysis of 65 RCTs, encompassing 72 interventions targeting sleep quality improvement, indicated that enhanced sleep mitigated symptoms of depression, anxiety, and stress.[41] Furthermore, our study showed that having a sleep partner decreased the weekly frequency of EUB. This reduction could be associated with the positive mental health effects of bed-sharing,[45] which underscores the connection between anxiety and EUB. Therefore, we further speculate that participants with a high frequency of EUB may have experienced elevated anxiety during the COVID-19 pandemic.[6,8,9,19,22,37] Although our study did not use anxiety or depression scales, preventing a direct causal inference between EUB and mood disturbance, there's evident interaction between these factors. Further research is needed to elucidate this relationship.

Psychological factors are known to be linked to the nocebo effect,[25,46] the frequency of EUB, and sleep quality.[19] Consistent with this, our study found that participants who frequently experienced EUB or had unsatisfactory sleep were at a greater risk of reporting CAEs after receiving COVID-19 vaccine. These associations remained significant even after the adjustment of covariates, including various sleep parameters (**Table 5**). Furthermore, our research supports previous findings that CAEs are more common among women and younger individuals, highlighting the observed age and sex differences.[47]

Our study revealed some noteworthy findings regarding alcohol consumption. Participants with higher alcohol consumption (measured in grams per week) and heavy drinking had a lower risk of CAEs. Two potential explanations are as follows: first, excessive alcohol intake may modulate immunity, potentially reducing COVID-19 vaccine effectiveness.[48] Second, it could be a defense mechanism against increasing anxiety and stress from COVID-19 pandemic-related social circumstances, possibly decreasing it. Following the global lockdown, alcohol consumption significantly increased,[48,49] particularly in South Korea, where drinking is a popular leisure activity linked to peer pressure.[32,49] In a study of middle-aged Korean adults during the COVID-19 pandemic, higher friend support led to excessive alcohol consumption.[49] Further, a Vietnamese study found that sharing emotions with friends reduced anxiety and stress during the COVID-19 pandemic.[39] Therefore, owing to the friend support gained by alcohol consumption, stable mental health may have protected participants against CAEs in our study by reducing the frequency of the nocebo effect.

This study had some limitations. First, since our study did not include mental health questionnaires, we assumed that excessive EUB is related to mood disturbances, such as depression or anxiety, to interpret our results. However, previous studies[17] have confirmed that EUB is significantly associated with PSU, which has been linked to anxiety and depression.[6,8,35] Additionally, an earlier study has reported a direct relationship between bedtime smartphone use and mood disturbances.[30] Second, the causality among EUB frequency, mental health, sleep, and CAEs was difficult to infer from our cross-sectional study. However, an intervention that restricted mobile phone use before bedtime for four weeks showed improved sleep status, positive affect, and working memory in a previous study.[44] Further research is needed to clarify the causality and develop treatments for patients with frequent EUB or sleep and mood disturbances. Third, it is difficult to generalize our results because our study included Korean adults during a specific period: the COVID-19 pandemic. Average smartphone use and the prevalence of PSU were found to be significantly higher in Korea than in other countries.[1,50] Additionally, the COVID-19 pandemic has been associated with high levels of mood disturbances worldwide, including stress, anxiety and depression.[23,37] Moreover, the survey time for the frequency of EUB and sleep profile does not precisely align with the time when CAEs occurred. As a result, the association between EUB, sleep, and CAEs may have been overestimated. Finally, our results were not adjusted for participants' physical comorbidities, which could affect their sleep quality and mood disturbances, because our questionnaire focused solely on sleep status or sleep disorders.

In conclusion, we found that participants with a higher frequency of EUB were more likely to report poorer sleep and CAEs after the COVID-19 vaccination during the pandemic compared with those with a lower frequency of EUB. We hypothesized that mood disturbances might act as intervening factors in these associations. However, to further support our suggestions, additional studies are required with improved research methods. These should include questionnaires to evaluate mental health of participants from diverse countries.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

CHERRIES checklist for web-based studies (adapted from Eysenbach 2004)

Click here to view

Supplementary Fig. 1

The percentage of participants with COVID-19 vaccine-related adverse events according to the weekly frequency of electronic device use at bedtime. *P* value derived from linear by linear association.

Click here to view

REFERENCES

1. Islam M. Link between Excessive smartphone use and sleeping disorders and depression among South Korean university students. *Healthcare (Basel)* 2021;9(9):1213.
PUBMED | CROSSREF

2. Statista. Ownership rate of smartphones in South Korea from 2011 to 2021. https://www.statista.com/statistics/777726/south-korea-smartphone-ownership/. Updated 2022. Accessed June 1, 2023.
3. Wacks Y, Weinstein AM. Excessive smartphone use is associated with health problems in adolescents and young adults. *Front Psychiatry* 2021;12:669042.
PUBMED | CROSSREF
4. Weinstein A, Siste K. Editorial: excessive and problematic smartphone usage. *Front Psychiatry* 2022;13:972613.
PUBMED | CROSSREF
5. Zou Y, Xia N, Zou Y, Chen Z, Wen Y. Smartphone addiction may be associated with adolescent hypertension: a cross-sectional study among junior school students in China. *BMC Pediatr* 2019;19(1):310.
PUBMED | CROSSREF
6. Pera A. The psychology of addictive smartphone behavior in young adults: problematic use, social anxiety, and depressive stress. *Front Psychiatry* 2020;11:573473.
PUBMED | CROSSREF
7. Elhai JD, Levine JC, Dvorak RD, Hall BJ. Non-social features of smartphone use are most related to depression, anxiety, and problematic smartphone use. *Comput Human Behav* 2017;69:75-82.
CROSSREF
8. Elhai JD, Dvorak RD, Levine JC, Hall BJ. Problematic smartphone use: a conceptual overview and systematic review of relations with anxiety and depression psychopathology. *J Affect Disord* 2017;207:251-9.
PUBMED | CROSSREF
9. Geng Y, Gu J, Wang J, Zhang R. Smartphone addiction and depression, anxiety: the role of bedtime procrastination and self-control. *J Affect Disord* 2021;293:415-21.
PUBMED | CROSSREF
10. Panova T, Carbonell X. Is smartphone addiction really an addiction? *J Behav Addict* 2018;7(2):252-9.
PUBMED | CROSSREF
11. Olson JA, Sandra DA, Colucci ÉS, Al Bikaii A, Chmoulevitch D, Nahas J, et al. Smartphone addiction is increasing across the world: a meta-analysis of 24 countries. *Comput Human Behav* 2022;129:107138.
CROSSREF
12. Huckins JF, daSilva AW, Wang W, Hedlund E, Rogers C, Nepal SK, et al. Mental health and behavior of college students during the early phases of the COVID-19 pandemic: longitudinal smartphone and ecological momentary assessment study. *J Med Internet Res* 2020;22(6):e20185.
PUBMED | CROSSREF
13. Zhang MX, Chen JH, Tong KK, Yu EW, Wu AM. Problematic smartphone use during the COVID-19 pandemic: its association with pandemic-related and generalized beliefs. *Int J Environ Res Public Health* 2021;18(11):5724.
PUBMED | CROSSREF
14. Wang PY, Chen KL, Yang SY, Lin PH. Relationship of sleep quality, smartphone dependence, and health-related behaviors in female junior college students. *PLoS One* 2019;14(4):e0214769.
PUBMED | CROSSREF
15. Carter B, Rees P, Hale L, Bhattacharjee D, Paradkar MS. Association between portable screen-based media device access or use and sleep outcomes: a systematic review and meta-analysis. *JAMA Pediatr* 2016;170(12):1202-8.
PUBMED | CROSSREF
16. Zhang MX, Wu AM. Effects of smartphone addiction on sleep quality among Chinese university students: the mediating role of self-regulation and bedtime procrastination. *Addict Behav* 2020;111:106552.
PUBMED | CROSSREF
17. Paik SH, Park CH, Kim JY, Chun JW, Choi JS, Kim DJ. Prolonged bedtime smartphone use is associated with altered resting-state functional connectivity of the insula in adult smartphone users. *Front Psychiatry* 2019;10:516.
PUBMED | CROSSREF
18. Rod NH, Dissing AS, Clark A, Gerds TA, Lund R. Overnight smartphone use: A new public health challenge? A novel study design based on high-resolution smartphone data. *PLoS One* 2018;13(10):e0204811.
PUBMED | CROSSREF
19. Appleton SL, Reynolds AC, Gill TK, Melaku YA, Adams R. Waking to use technology at night, and associations with driving and work outcomes: a screenshot of Australian adults. *Sleep (Basel)* 2020;43(8):zsaa015.
PUBMED | CROSSREF

20. Zhang C, Zeng P, Tan J, Sun S, Zhao M, Cui J, et al. Relationship of problematic smartphone use, sleep quality, and daytime fatigue among quarantined medical students during the COVID-19 pandemic. *Front Psychiatry* 2021;12:755059.
PUBMED | CROSSREF

21. Bhat S, Chokroverty S. Sleep disorders and COVID-19. *Sleep Med* 2022;91:253-61.
PUBMED | CROSSREF

22. Deng Y, Ye B, Yang Q. COVID-19 Related emotional stress and bedtime procrastination among college students in china: a moderated mediation model. *Nat Sci Sleep* 2022;14:1437-47.
PUBMED | CROSSREF

23. Meaklim H, Junge MF, Varma P, Finck WA, Jackson ML. Pre-existing and post-pandemic insomnia symptoms are associated with high levels of stress, anxiety, and depression globally during the COVID-19 pandemic. *J Clin Sleep Med* 2021;17(10):2085-97.
PUBMED | CROSSREF

24. Haas JW, Bender FL, Ballou S, Kelley JM, Wilhelm M, Miller FG, et al. Frequency of adverse events in the placebo arms of COVID-19 vaccine trials: a systematic review and meta-analysis. *JAMA Netw Open* 2022;5(1):e2143955.
PUBMED | CROSSREF

25. Benedetti F, Lanotte M, Lopiano L, Colloca L. When words are painful: unraveling the mechanisms of the nocebo effect. *Neuroscience* 2007;147(2):260-71.
PUBMED | CROSSREF

26. Barsky AJ, Saintfort R, Rogers MP, Borus JF. Nonspecific medication side effects and the nocebo phenomenon. *JAMA* 2002;287(5):622-7.
PUBMED | CROSSREF

27. Solís Arce JS, Warren SS, Meriggi NF, Scacco A, McMurry N, Voors M, et al. COVID-19 vaccine acceptance and hesitancy in low- and middle-income countries. *Nat Med* 2021;27(8):1385-94.
PUBMED | CROSSREF

28. Webster RK, Weinman J, Rubin GJ. A systematic review of factors that contribute to nocebo effects. *Health Psychol* 2016;35(12):1334-55.
PUBMED | CROSSREF

29. Bhat S, Pinto-Zipp G, Upadhyay H, Polos PG. "To sleep, perchance to tweet": in-bed electronic social media use and its associations with insomnia, daytime sleepiness, mood, and sleep duration in adults. *Sleep Health* 2018;4(2):166-73.
PUBMED | CROSSREF

30. Dissing AS, Andersen TO, Jensen AK, Lund R, Rod NH. Nighttime smartphone use and changes in mental health and wellbeing among young adults: a longitudinal study based on high-resolution tracking data. *Sci Rep* 2022;12(1):8013.
PUBMED | CROSSREF

31. Kim J, Kang KW, Kim KT, Cho YW. Prevalence of restless legs syndrome during the 2019 coronavirus disease pandemic in South Korea: a nationwide cross-sectional population-based study. *Front Neurol* 2022;13:1101711.
PUBMED | CROSSREF

32. Jung JG, Kim JS, Yoon SJ, Lee S, Ahn SK. Korean alcohol guidelines for primary care physicians. *Korean J Fam Pract* 2021;11(1):14-21.
CROSSREF

33. AlShareef SM. The impact of bedtime technology use on sleep quality and excessive daytime sleepiness in adults. *Sleep Sci* 2022;15 Spec 2:318-27.
PUBMED | CROSSREF

34. Exelmans L, Van den Bulck J. Bedtime mobile phone use and sleep in adults. *Soc Sci Med* 2016;148:93-101.
PUBMED | CROSSREF

35. Thomée S. Mobile phone use and mental health. a review of the research that takes a psychological perspective on exposure. *Int J Environ Res Public Health* 2018;15(12):2692.
PUBMED | CROSSREF

36. Kroese FM, Evers C, Adriaanse MA, de Ridder DT. Bedtime procrastination: a self-regulation perspective on sleep insufficiency in the general population. *J Health Psychol* 2016;21(5):853-62.
PUBMED | CROSSREF

37. Meng D, Zhao Y, Guo J, Xu H, Fu Y, Ma X, et al. Time perspective and bedtime procrastination: the role of the chronotype-time perspective relationship. *Nat Sci Sleep* 2021;13:1307-18.
PUBMED | CROSSREF

38. Morin CM, Bjorvatn B, Chung F, Holzinger B, Partinen M, Penzel T, et al. Insomnia, anxiety, and depression during the COVID-19 pandemic: an international collaborative study. *Sleep Med* 2021;87:38-45.
PUBMED | CROSSREF

39. Doan LP, Nguyen LH, Do HN, Nguyen TT, Vu LG, Do HP, et al. Protecting mental health of young adults in COVID-19 pandemic: roles of different structural and functional social supports. *PLoS One* 2022;17(11):e0276042.
PUBMED | CROSSREF

40. Magalhã P, Cruz V, Teixeira S, Fuentes S, Rosário P. An exploratory study on sleep procrastination: Bedtime vs. while-in-bed procrastination. *Int J Environ Res Public Health* 2020;17(16):5862.
PUBMED

41. Scott AJ, Webb TL, Martyn-St James M, Rowse G, Weich S. Improving sleep quality leads to better mental health: a meta-analysis of randomised controlled trials. *Sleep Med Rev* 2021;60:101556.
PUBMED | CROSSREF

42. Yasugaki S, Okamura H, Kaneko A, Hayashi Y. Bidirectional relationship between sleep and depression. *Neurosci Res*. Forthcoming 2023. DOI: 10.1016/j.neures.2023.04.006.
PUBMED | CROSSREF

43. Chi S, Ko MS, Lee JH, Yi HS, Lee MS. Smartphone usage and sleep quality in Korean middle school students during the COVID-19 pandemic. *Psychiatry Investig* 2022;19(9):722-8.
PUBMED | CROSSREF

44. He JW, Tu ZH, Xiao L, Su T, Tang YX. Effect of restricting bedtime mobile phone use on sleep, arousal, mood, and working memory: a randomized pilot trial. *PLoS One* 2020;15(2):e0228756.
PUBMED | CROSSREF

45. Fuentes B, Kennedy K, Killgore W, Wills C, Grandner M. 0010 Bed sharing versus sleeping alone associated with sleep health and mental health. *Sleep* 2022;45(Suppl 1):A4.
CROSSREF

46. Geers AL, Clemens KS, Faasse K, Colagiuri B, Webster R, Vase L, et al. Psychosocial factors predict COVID-19 vaccine side effects. *Psychother Psychosom* 2022;91(2):136-8.
PUBMED | CROSSREF

47. Urakawa R, Isomura ET, Matsunaga K, Kubota K, Ike M. Impact of age, sex and medical history on adverse reactions to the first and second dose of BNT162b2 mRNA COVID-19 vaccine in Japan: a cross-sectional study. *BMC Infect Dis* 2022;22(1):179.
PUBMED | CROSSREF

48. Solopov PA. COVID-19 vaccination and alcohol consumption: justification of risks. *Pathogens* 2023;12(2):163.
PUBMED | CROSSREF

49. Maeng SJ, Kim KH, Kang JH. The impact of social supports on the excessive alcohol use of the middle-aged adults in South Korea: do all types of social supports have positive effects on excessive alcohol users? *Int J Environ Res Public Health* 2022;19(19):12624.
PUBMED | CROSSREF

50. Winskel H, Kim TH, Kardash L, Belic I. Smartphone use and study behavior: a Korean and Australian comparison. *Heliyon (Lond)* 2019;5(7):e02158.
PUBMED | CROSSREF