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Relationship Between Mental Health Status (Depression, Anxiety, and Loneliness) and Screen Time among University Students During the COVID-19 Pandemic: The Mediating Role of Sleep Status

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©Relationship Between Mental Health Status (Depression, Anxiety, and Loneliness) and Screen Time among University Students During the COVID-19 Pandemic: The Mediating Role of Sleep Status

Wei Wang#, Jingfeng Jiang#*, Lerong Qi, Fanqi Zhao, Jingying Wu, Xiaoqi Zhu, Xiang Hong,* Bei Wang

1. Key Laboratory of Environmental Medicine and Engineering of Ministry of Education, Department of Epidemiology and Health Statistics, School of Public Health, Southeast University, Nanjing, Jiangsu, China
2. Wuxi Center for Disease Control and Prevention

# These authors contributed equally to this work and should be considered co-first authors.

* Corresponding author: Xiang Hong, 87#, Dingjiaqiao Road, Gulou District, Nanjing City, Jiangsu Province, China. 210009. Email: hongxiang@seu.edu.cn

Jingfeng Jiang, 499 Jincheng Road, Liangxi District, Wuxi City, Jiangsu Province, China. Email: jjf870122@163.com

Abstract

Objective: On July 20, 2021, after the outbreak of COVID-19 at Nanjing Lukou International Airport, several universities started closed management and online teaching. This had a large impact on students' daily life and study, which may lead to mental health problems. The purpose of this study is to study the effect of screen time on mental health status of university students and the possible mediating effect of sleep status.

Methods: This was a cross-sectional study. A web-based questionnaire survey was employed that included demographic characteristics, sleep status, and mental health status (depression, anxiety, and loneliness). The Pittsburgh Sleep Quality Index scale was used to assess sleep status, while the Center for Epidemiologic Studies Depression (CES-D) scale, Generalized Anxiety Disorder-7 (GAD-7) scale, and Emotional versus Social Loneliness Scale (ESLS) were used to assess depression, anxiety, and loneliness, respectively. Linear and logistic regression models were developed and adjusted for confounding factors, and finally the mediating effects were tested using the Karlson-Holm-Breen (KHB) method.

Results: Finally, 1070 valid questionnaires were included. Among these, 604 (56.45%) indicated depressive symptoms (CES-D score $\geq$ 16) and 902 (84.30%) indicated anxiety symptoms (GAD-7 score $\geq$ 10). The mean ESLS score (for loneliness) was 26.51 $\pm$ 6.64. The relationship between screen time and depressive symptoms (OR = 1.118, 95% CI = 1.072–1.166) and anxiety symptoms (OR = 1.079, 95% CI = 1.023–1.138) remained significant after adjusting for confounding factors. Meanwhile, sleep status plays an intermediary role in screen time and mental health status (depression and anxiety) and accounts for 13.73% and 19.68% of the total effects, respectively. We did not find a significant association between screen time and loneliness.

Conclusion: During the outbreak of COVID-19, screen time is inevitably prolonged among university students. The impact on the mental health status of university students may be reduced by improving their sleep status. Schools and universities should take mental health care measures during outbreaks.

Keywords: screen time; sleep status; depression; anxiety; loneliness

Strengths and limitations of this study

The first multi-angle study of screen time, sleep status, and mental health status of college students

during the COVID-19 pandemic including mediation effects.

Internationally recognized scales are used to estimate mental health, so the results are comparable

to those of other studies.

The potential confounding factors were adjusted for and many sensitivity analyses were conducted,

so the results are robust.

This is a cross-sectional study, which is weak in causal inference and has the risk of reverse causality.

Due to the use of online questionnaire, there may be selection bias and information bias.

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1 Introduction

On July 20th, 2021, nine Nanjing Lukou International Airport staff tested positive for SARS-CoV-2[1]. The government has sought to contain the spread of COVID-19 through lockdowns, limiting travel, and stimulating people to maintain distance. Many parts of Nanjing have been designated as risk or control areas, and several universities have implemented measures such as closed management and online teaching. In this context, COVID-19 also has a significant impact on mental health[2-4]. University students are at an important transition stage in their lives and face a unique set of challenges. Therefore, there is a need to pay attention to the impact of the COVID-19 pandemic on the mental health of university students. Some studies have shown that the psychological pressure on college students caused by COVID-19 is particularly prominent in different age groups[5 6]. During the pandemic, screen time is inevitably prolonged among students, and little is known about the exact impact of the COVID-19 pandemic on the mental health of university students.

When universities carry out closed management, the screen time of university students is bound to be extended. Screen time is divided into several areas, such as studying and working, browsing news, and socializing. Excessive screen time can affect adolescents' brain function and cognitive ability[7]. The consequences of increased screen time in the wake of the pandemic have been analyzed. A study from China concluded that screen time (specifically, time spent studying) is negatively associated with mood status[8], and another study concluded that screen time is correlated with the severity of depression and anxiety[9]. Excessive screen time can also lead to increased feelings of loneliness[5]. Some studies suggest that outdoor activity or exposure to nature (green time) may diminish the effects of increased screen time[10 11], but apparently, green time does not increase when university students are in closed management.

Lack of sleep affects the physical and mental health and psychosocial function of young people. Studies suggest that excessive screen time can lead to a lack of sleep in different ways: Screen time can replace sleep time[12]; the strong light emitted by electronic devices before going to bed can inhibit the production of melatonin and cause circadian rhythm disorder[13]; and teenagers using social media before going to bed not only shorten their sleep time[14], but are also awakened by notifications at night[15]. Sleep problems are often accompanied by mental health problems such as depression and anxiety, and are even used as predictors of psychological problems[16]. Therefore, we

put forward the hypothesis that screen time can affect the mental health of university students, and sleep status plays an intermediary role. Our study provides new ideas for mental health intervention in college students during epidemic prevention and control.

2 Materials and Methods

2.1 Study Design and Sample

This cross-sectional study was conducted from August 1 to September 31, 2021. The participants were university students studying in China, aged 18–30 years, with no requirements on gender and major. The questionnaire was distributed online and widely disseminated after the pre-experiment. The detailed questionnaire selection process is shown in Figure S1. Finally, 1070 valid questionnaires were included.

The survey was completely anonymous. The purpose of the study was detailed in the questionnaire guidelines. Informed consent was provided by all participants. Permissions for the questionnaire were set (every IP address can only be used once) to prevent duplication. All questions in the questionnaire were set as required fields to ensure data integrity. This study was approved by the Ethics Committee of Zhongda Hospital, Southeast University.

2.2 Measures

2.2.1 Screen Time

Screen time is defined as the total time spent per day in front of a screen of any electronic device, including mobile phones, tablets, and e-books. Screen time is divided into four parts according to the purpose of the screen time: work and study, social activities, audio-visual entertainment, and shopping and takeaway. These classifications are reported by the respondents themselves. In the present study, 18 questionnaires reporting a total of more than 24 hours of screen time per day were excluded (Figure S1).

2.2.2 Sleep Status

Sleep status was assessed using the Pittsburgh Sleep Quality Index (PSQI), a 19-item scale subdivided into seven parts, i.e., (i) sleep duration, (ii) sleep disturbance, (iii) sleep latency, (iv) daytime dysfunction due to sleepiness, (v) sleep efficiency, (vi) overall sleep quality, and (vii) sleep medication use[17], with a score of 0–3 for each section and thus a maximum total score of 21. A total score of 5 is often used as the critical value to judge sleep status[18-20], where PSQI < 5 is considered

good sleep quality and PSQI $\geq$ 5 is considered bad sleep quality.

2.2.3 Mental Health Status

In the present study, mental health status was assessed based on depression, anxiety, and loneliness.

Depression was assessed using the Center for Epidemiologic Studies Depression (CES-D) scale[21], which is a brief self-report scale containing 20 items with a maximum total score of 60. CES-D $\geq$ 16 is generally considered to indicate depressive symptoms[22-24].

Anxiety was assessed with the Generalized Anxiety Disorder-7 (GAD-7) scale[25], which is also a self-rating scale. The scale has seven items, each with a score of 0–3 points, reaching a maximum total score of 21 points. A GAD-7 score of $\geq$ 10 is generally considered to indicate anxiety symptoms.

The Emotional versus Social Loneliness Scale (ESLS)[26] was used to evaluate loneliness. The ESLS utilizes 10 items to evaluate emotional and social loneliness on a scale of 0–5 for each question, with higher scores indicating more intense loneliness.

2.2.4 Covariates

General demographic characteristics and exercise status were included as covariates. General demographic characteristics included: gender, region (Nanjing, non-Nanjing), education (bachelor, master, PhD), type of major (engineering, medicine, liberal arts, other), cost of living (<1000, 1000–2000, 2000–3000, >3000 yuan) and change in sports time (decrease, no change, increase) between before and after the COVID-19 outbreak.

2.3 Statistical Analysis

A database with all collected questionnaire data was created. The total scores were calculated and invalid data were eliminated. Continuous variables are presented as mean and standard deviation, and categorical variables are presented as absolute values and proportions. The *t*-test, chi-square test, or Spearman's coefficient test was selected for correlation analysis between variables. The relationships between independent and dependent variables and between independent and mediating variables were examined using logistic regression models (results for dichotomous variables) or linear regression models (results for continuous variables). Two models were developed to account for possible confounders: a crude model without adjusting for any confounders and an adjusted model controlling for differences in gender, region, education level, type of profession, cost of living, and time spent doing exercise. After controlling for confounding factors,

we also further tested whether the relationship between screen time and mental health status changed when the mediating variable (sleep status) was included. Finally, because the mediating variable was dichotomous and the dependent variable had dichotomous and continuous variables, we used the Karlson-Holm-Breen (KHB) method[27] to calculate the model's total, direct, and indirect effects. We considered a profile effect significant if its confidence interval (CI) did not include zero.

2.4 Patient and public involvement

The study participants were not involved in the design of this study.

3 Result

3.1 Participant characteristics

In total, 1070 participants were included. The demographic characteristics of the study population are shown in Table 1. Males accounted for 43.08%, the number of undergraduate students was the largest (826, 77.20%), engineering students accounted for 38.60%, most people's cost of living was in the range of 1000–2000 yuan, accounting for 58.04%, and after the emergence of the pandemic, 76.92% of university students had the same or reduced exercise time. The distribution of screen time and sleep status across mental health conditions is given in Table 2. Worse psychological conditions such as depressive symptoms and anxiety symptoms were associated with longer screen time (depression: 7.79 h vs. 8.83 h, $P < 0.001$; anxiety: 7.98 h vs. 8.85 h, $P = 0.001$), but similar results were not observed for loneliness symptoms. Poor sleep status tended to be associated with poor mental health status, as did loneliness symptoms. The proportions of people with good sleep and bad sleep are different across mental health conditions (without depression: 47.4% vs. 52.6%; with depression: 14.7% vs. 85.3%; without anxiety: 41.6% vs. 58.4%; with anxiety: 13.7% vs. 86.3%). The loneliness score was also lower among people with good sleep than among people with bad sleep (24.98 vs. 27.42, $P < 0.001$).

3.2 Association of Screen Time with Sleep Status and Mental Health Status

Table 3 shows the relationship between screen time and mental health status. In the crude model without adjusting for any confounder, longer screen time was significantly associated with depressive symptoms and anxiety symptoms (depression: odds ratio [OR] = 1.107, 95% CI = 1.065–1.151; anxiety: OR = 1.084, 95% CI = 1.032–1.139), but not with loneliness status (β = 0.032, 95% CI = −0.091 to 0.156). After adjusting for potential confounding factors such as cost of living and

changes in exercise time, the relationship between screen time and depressive symptoms (OR = 1.118, 95% CI = 1.072–1.166) and anxiety symptoms (OR = 1.079, 95% CI = 1.023–1.138) remained significant, while the relationship between screen time and loneliness symptoms remained not statistically significant (β = 0.106, 95% CI = −0.023 to 0.237). Table 3 also shows that increased screen time is a risk factor for sleep status in both the unadjusted crude model (OR = 1.069, 95% CI = 1.027–1.112) and the model after adjusting for confounding factors (OR = 1.049, 95% CI = 1.005–1.095).

3.3 Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status

The mediation effect of sleep status between screen time and mental health status (depression and anxiety) is shown in Table 4. After controlling for screen time ($P < 0.05$) and other covariates, poor sleep status was a risk factor for depressive symptoms (OR = 5.044, 95% CI = 3.746–6.793) and anxiety symptoms (OR = 4.449, 95% CI = 2.781–7.117). The relationship between increased screen time and depressive symptoms (OR = 1.115, 95% CI = 1.066–1.166) and anxiety symptoms (OR = 1.067, 95% CI = 1.010–1.128) remained significant after the inclusion of mediating variables in the model.

The analysis of mediation effects showed that screen time had a significant indirect effect on both depressive symptoms (indirect effect = 0.0173, $P < 0.05$) (Figure 1A) and anxiety symptoms (indirect effect = 0.0076, $P < 0.05$) (Figure 1B) through sleep status after controlling for all covariates. As demonstrated in Table 4, the relative proportions of intermediaries are 13.73% and 19.68%, respectively.

3.4 Sensitivity Analysis

To ensure robustness of the results, we repeated the above analysis after transformation of variables. The results are presented in the Supplementary Material. As shown in Tables S1–S6, when we used the PSQI score as a continuous variable to indicate sleep status, the mediating effect of sleep status between screen time and depressive symptoms and between screen time and anxiety symptoms was increased (depression: indirect effect = 0.044, 95% CI = 0.022–0.066, proportion of mediation = 32.89%; anxiety: indirect effect = 0.046, 95% CI = 0.023–0.068, proportion of mediation = 57.48%). As shown in Tables S1–S9, no association was found between screen time and loneliness symptoms, either using the ESLS score as a continuous variable to represent

loneliness symptoms or using loneliness symptoms as a dichotomous variable according to the median ESLS score (median = 26).

4 Discussion

In the present study, we investigated the relationship between screen time, sleep status, and mental health status among university students. The study was conducted shortly after the COVID-19 outbreak at Nanjing Lukou International Airport. We focused on the effects of university closure on students. Our study showed that among university students, screen time was associated with depression and anxiety. No significant relationship between screen time and loneliness was observed. Sleep status partially mediated the effects of screen time on depression and anxiety. This survey was conducted among university students during a COVID-19 outbreak to provide suggestions for healthy care measures at universities during outbreaks.

Logistic regression analysis showed that after adjusting for confounding effects, the proportions of students with depressive symptoms and with anxiety symptoms were higher among university students with long screen time. Several studies conducted in China and abroad have shown that excessive screen time is positively associated with mental health status among university students[28-32]. As for the reason for this correlation, some researchers believe that during COVID-19 outbreaks, we get a lot of negative information through electronic media, but the quality of such information is uncontrollable. In addition, fragmented information is prevalent, which leads to an increase in our negative emotions and possibly also to symptoms of depression and anxiety[33-36]. In public health emergencies, negative information can be amplified with the influx of information, resulting in more serious consequences[37]. In addition, studies have found that longer screen time in adolescents is associated with a decreased attention span[38], violent tendencies[39], and low self-esteem[40], all of which are proven risk factors for mental health conditions[41].

The results also showed that screen time and sleep status were negatively correlated, and sleep status partially mediated the relationship between screen time and both depression and anxiety, accounting for 13.73% and 19.68% of the total effects, respectively. Excessive screen time may affect melatonin secretion[13] and sleep is also affected by nighttime notifications[15]. In addition, video games may lead to mental arousal and thus affect sleep[42], and the violent content of video games has a particularly pronounced effect on sleep conditions[43]. University students are often surrounded

by a large number of electronic devices, especially in places such as dormitories where the division

of areas is not clear, and the hindrance to their sleep is very obvious [44]. In addition, even if the screen

is turned off, electromagnetic radiation may still be perceived as light by the pineal gland, thus

affecting the secretion of melatonin and causing sleep difficulties[45]. Sleep status was included in the

present study because sleep status affects physical and psychological functions in young people,

including anxiety and depression[46], which may be related to poor sleep, dysfunction of the

cholinergic neurotransmitter system and the prefrontal cortex, and increased limbic system activity[47].

Moreover, sleep disorders can cause abnormal hormone secretion by interfering with the function

of the hypothalamus–pituitary–adrenal   axis, which may make the body more sensitive to stress

factors in the environment and may induce psychological problems[48].

The present study has several strengths. First, this study is the first multi-angle study of screen

time, sleep status, and mental health status of college students during the COVID-19 pandemic

including mediation effects. This is of great significance for the formulation of epidemic prevention

and control strategies. Second, we used internationally recognized scales to estimate the mental

health status, so the results are comparable with those of other studies. Third, the potential

confounding factors were adjusted for and many sensitivity analyses were conducted, so the results

are robust.

However, there were still some limitations in this study that need to be carefully considered.

First, this is a cross-sectional study, which is weak in causal inference and has the risk of reverse

causality. Second, the online questionnaire survey may result in selection bias and information bias.

Third, the evaluation of some covariates is not accurate, such as the change in sports time. More

accurate indicators to evaluate exercise should be considered, such as the International Physical

Activity questionnaire[49]. Finally, there is the possibility of bias due to unmeasured confounding

factors, such as the study subjects' living habits and personality.

In the context of COVID-19 prevention and control, the prolonged use of electronic devices

by university students is unavoidable, but sleep quality can be improved by rationalizing the work

schedule, improving the sleep environment, and timely correcting sleep problems, thus mitigating

the effects of increased screen time on mental health status. Schools and universities should also

provide health care measures to ensure the physical and mental health of students. A longitudinal

study should be conducted in the future to further investigate the association between screen time

and mental health status.

5 Conclusion

After controlling for confounding factors, increased screen time among university students was found to be positively associated with depressive symptoms and anxiety symptoms. Sleep status plays a partially mediating role. Our results suggest that we can regulate mental health by improving sleep status.

Author contribution statement

Xiang Hong designed the study, and carried it out with contributions from all authors. Wei Wang and Jingfeng Jiang analyzed the results and wrote the first draft, which was critically reviewed and approved by all authors. Lerong Qi, Fanqi Zhao, Jingying Wu, and Xiaoqi Zhu conducted a questionnaire survey through the Internet and excluded the unqualified questionnaires.

Declaration of interests statement

The authors declare no conflict of interest.

References

1. Liu Y, Yang B, Liu L, et al. Occupational Characteristics in the Outbreak of the COVID-19 Delta Variant in Nanjing, China: Rethinking the Occupational Health and Safety Vulnerability of Essential Workers. *Int J Environ Res Public Health* 2021;18(20) doi: 10.3390/ijerph182010734 [published Online First: 2021/10/24]

2. Campion J, Javed A, Sartorius N, et al. Addressing the public mental health challenge of COVID-19. *The Lancet Psychiatry* 2020;7(8):657-59. doi: 10.1016/s2215-0366(20)30240-6

3. Serafini G, Parmigiani B, Amerio A, et al. The psychological impact of COVID-19 on the mental health in the general population. *QJM* 2020 doi: 10.1093/qjmed/hcaa201 [published Online First: 2020/06/23]

4. Garfin DR, Silver RC, Holman EA. The novel coronavirus (COVID-2019) outbreak: Amplification of public health consequences by media exposure. *Health Psychol* 2020;39(5):355-57. doi: 10.1037/hea0000875 [published Online First: 2020/03/24]

5. Lisitsa E, Benjamin KS, Chun SK, et al. Loneliness among young adults during COVID-19 pandemic: The mediational roles of social media use and social support seeking. 2020;39(8):708-26.

6. Browning M, Larson LR, Sharaievska I, et al. Psychological impacts from COVID-19 among university students: Risk factors across seven states in the United States. *PLoS One* 2021;16(1):e0245327. doi: 10.1371/journal.pone.0245327 [published Online First: 2021/01/08]

7. Yu L, Zhou X. Emotional Competence as a Mediator of the Relationship Between Internet Addiction and Negative Emotion in Young Adolescents in Hong Kong. *Applied Research in Quality of Life* 2021;16(6):2419-38. doi: 10.1007/s11482-021-09912-y

8. Xiao S, Yan Z, Zhao L. Physical Activity, Screen Time, and Mood Disturbance Among Chinese Adolescents During COVID-19. *J Psychosoc Nurs Ment Health Serv* 2021;59(4):14-20. doi: 10.3928/02793695-20201104-04 [published Online First: 2020/11/13]

9. Maras D, Flament MF, Murray M, et al. Screen time is associated with depression and anxiety in Canadian youth. *Prev Med* 2015;73:133-8. doi: 10.1016/j.ypmed.2015.01.029 [published Online First: 2015/02/07]

10. Wu X, Tao S, Zhang Y, et al. Low physical activity and high screen time can increase the risks of mental health problems and poor sleep quality among Chinese college students. *PLoS One* 2015;10(3):e0119607. doi: 10.1371/journal.pone.0119607 [published Online First: 2015/03/19]

11. Oswald TK, Rumbold AR, Kedzior SGE, et al. Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature. *Int J Environ Res Public Health* 2021;18(11) doi: 10.3390/ijerph18115630 [published Online First: 2021/06/03]

12. Cheung CH, Bedford R, Saez De Urabain IR, et al. Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. *Sci Rep* 2017;7:46104. doi: 10.1038/srep46104 [published Online First: 2017/04/14]

13. Figueiro M, Overington D. Self-luminous devices and melatonin suppression in adolescents. *Lighting Research & Technology* 2015;48(8):966-75. doi: 10.1177/1477153515584979

14. Grover K, Pecor K, Malkowski M, et al. Effects of Instant Messaging on School Performance in Adolescents. 2016;31(7):850-57. doi: 10.1177/0883073815624758

15. Falbe J, Davison KK, Franckle RL, et al. Sleep Duration, Restfulness, and Screens in the Sleep Environment. *Pediatrics* 2015;135(2):e367-e75. doi: 10.1542/peds.2014-2306 %J Pediatrics

16. Marinelli M, Sunyer J, Alvarez-Pedrerol M, et al. Hours of television viewing and sleep duration in

children: a multicenter birth cohort study. *JAMA Pediatr* 2014;168(5):458-64. doi: 10.1001/jamapediatrics.2013.3861 [published Online First: 2014/03/13]

17. Buysse DJ, Reynolds CF, 3rd, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res* 1989;28(2):193-213. doi: 10.1016/0165-1781(89)90047-4 [published Online First: 1989/05/01]

18. Bertolazi AN, Fagondes SC, Hoff LS, et al. Validation of the Brazilian Portuguese version of the Pittsburgh Sleep Quality Index. *Sleep Med* 2011;12(1):70-5. doi: 10.1016/j.sleep.2010.04.020 [published Online First: 2010/12/15]

19. Barazzetti L, Garcez A, Freitas Sant'Anna PC, et al. Does sleep quality modify the relationship between common mental disorders and chronic low back pain in adult women? *Sleep Med* 2022;96:132-39. doi: 10.1016/j.sleep.2022.05.006 [published Online First: 2022/06/07]

20. Halson SL, Johnston RD, Appaneal RN, et al. Sleep Quality in Elite Athletes: Normative Values, Reliability and Understanding Contributors to Poor Sleep. *Sports Med* 2022;52(2):417-26. doi: 10.1007/s40279-021-01555-1 [published Online First: 2021/09/24]

21. Radloff LSJApm. The CES-D scale: A self-report depression scale for research in the general population. 1977;1(3):385-401.

22. Costantine MM, Smith K, Thom EA, et al. Effect of Thyroxine Therapy on Depressive Symptoms Among Women With Subclinical Hypothyroidism. *Obstet Gynecol* 2020;135(4):812-20. doi: 10.1097/AOG.0000000000003724 [published Online First: 2020/03/14]

23. Li Z, Hicks MH. The CES-D in Chinese American women: construct validity, diagnostic validity for major depression, and cultural response bias. *Psychiatry Res* 2010;175(3):227-32. doi: 10.1016/j.psychres.2009.03.007 [published Online First: 2009/12/17]

24. Vilagut G, Forero CG, Barbaglia G, et al. Screening for Depression in the General Population with the Center for Epidemiologic Studies Depression (CES-D): A Systematic Review with Meta-Analysis. *PLoS One* 2016;11(5):e0155431. doi: 10.1371/journal.pone.0155431 [published Online First: 2016/05/18]

25. Spitzer RL, Kroenke K, Williams JB, et al. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Archives of internal medicine* 2006;166(10):1092-7. doi: 10.1001/archinte.166.10.1092 [published Online First: 2006/05/24]

26. Shaver PR, Brennan KAJMPSPA. Measures of depression. 1991;1:195-289.

27. Kohler U, Karlson KB, Holm AJTSJ. Comparing coefficients of nested nonlinear probability models. 2011;11(3):420-38.

28. Feng Q, Zhang QL, Du Y, et al. Associations of physical activity, screen time with depression, anxiety and sleep quality among Chinese college freshmen. *PLoS One* 2014;9(6):e100914. doi: 10.1371/journal.pone.0100914 [published Online First: 2014/06/26]

29. Li X, Vanderloo LM, Keown-Stoneman CDG, et al. Screen Use and Mental Health Symptoms in Canadian Children and Youth During the COVID-19 Pandemic. *JAMA Netw Open* 2021;4(12):e2140875. doi: 10.1001/jamanetworkopen.2021.40875 [published Online First: 2021/12/29]

30. Liu M, Wu L, Yao S. Dose-response association of screen time-based sedentary behaviour in children and adolescents and depression: a meta-analysis of observational studies. *Br J Sports Med* 2016;50(20):1252-58. doi: 10.1136/bjsports-2015-095084 [published Online First: 2015/11/11]

31. Wang W, Du X, Guo Y, et al. Associations Among Screen Time, Sleep Duration and Depressive Symptoms Among Chinese Adolescents. *J Affect Disord* 2021;284:69-74. doi:

10.1016/j.jad.2021.01.082 [published Online First: 2021/02/15]

32. Zhang Y, Wu X, Tao S, et al. Associations between screen time, physical activity, and depressive symptoms during the 2019 coronavirus disease (COVID-19) outbreak among Chinese college students. *Environ Health Prev Med* 2021;26(1):107. doi: 10.1186/s12199-021-01025-0 [published Online First: 2021/11/04]

33. Chao M, Xue D, Liu T, et al. Media use and acute psychological outcomes during COVID-19 outbreak in China. *J Anxiety Disord* 2020;74:102248. doi: 10.1016/j.janxdis.2020.102248 [published Online First: 2020/06/09]

34. Dubey S, Biswas P, Ghosh R, et al. Psychosocial impact of COVID-19. *Diabetes Metab Syndr* 2020;14(5):779-88. doi: 10.1016/j.dsx.2020.05.035 [published Online First: 2020/06/12]

35. Holman EA, Garfin DR, Silver RC. Media's role in broadcasting acute stress following the Boston Marathon bombings. *Proc Natl Acad Sci U S A* 2014;111(1):93-8. doi: 10.1073/pnas.1316265110 [published Online First: 2013/12/11]

36. Resnyansky L. Social Media, Disaster Studies, and Human Communication. *IEEE Technology and Society Magazine* 2014;33(1):54-65. doi: 10.1109/mts.2014.2301857

37. Qin F, Song Y, Nassis GP, et al. Prevalence of insufficient physical activity, sedentary screen time and emotional well-being during the early days of the 2019 novel coronavirus (COVID-19) outbreak in China: a national cross-sectional study. 2020

38. Tamana SK, Ezeugwu V, Chikuma J, et al. Screen-time is associated with inattention problems in preschoolers: Results from the CHILD birth cohort study. *PLoS One* 2019;14(4):e0213995. doi: 10.1371/journal.pone.0213995 [published Online First: 2019/04/18]

39. Keikha M, Qorbani M, Kazemi Tabaee MS, et al. Screen Time Activities and Aggressive Behaviors Among Children and Adolescents: A Systematic Review. *Int J Prev Med* 2020;11:59. doi: 10.4103/ijpvm.IJPVM_71_20 [published Online First: 2020/06/25]

40. Braig S, Genuneit J, Walter V, et al. Screen Time, Physical Activity and Self-Esteem in Children: The Ulm Birth Cohort Study. *Int J Environ Res Public Health* 2018;15(6) doi: 10.3390/ijerph15061275 [published Online First: 2018/06/20]

41. Grontved A, Singhammer J, Froberg K, et al. A prospective study of screen time in adolescence and depression symptoms in young adulthood. *Prev Med* 2015;81:108-13. doi: 10.1016/j.ypmed.2015.08.009 [published Online First: 2015/08/26]

42. King DL, Delfabbro PH, Zwaans T, et al. Sleep Interference Effects of Pathological Electronic Media Use during Adolescence. *International Journal of Mental Health and Addiction* 2013;12(1):21-35. doi: 10.1007/s11469-013-9461-2

43. Oshima N, Nishida A, Shimodera S, et al. The suicidal feelings, self-injury, and mobile phone use after lights out in adolescents. *J Pediatr Psychol* 2012;37(9):1023-30. doi: 10.1093/jpepsy/jss072 [published Online First: 2012/06/26]

44. Hysing M, Pallesen S, Stormark KM, et al. Sleep and use of electronic devices in adolescence: results from a large population-based study. *BMJ Open* 2015;5(1):e006748. doi: 10.1136/bmjopen-2014-006748 [published Online First: 2015/02/04]

45. Halgamuge MN. Pineal melatonin level disruption in humans due to electromagnetic fields and ICNIRP limits. *Radiat Prot Dosimetry* 2013;154(4):405-16. doi: 10.1093/rpd/ncs255 [published Online First: 2012/10/12]

46. O'Brien LMJSMC. The neurocognitive effects of sleep disruption in children and adolescents. 2011;6(1):109-16.

47. Raniti MB, Allen NB, Schwartz O, et al. Sleep duration and sleep quality: associations with depressive symptoms across adolescence. 2017;15(3):198-215.

48. van Dalfsen JH, Markus CRJSmr. The influence of sleep on human hypothalamic–pituitary–adrenal (HPA) axis reactivity: A systematic review. 2018;39:187-94.

49. Doane LD, Gress-Smith JL, Breitenstein RS. Multi-method assessments of sleep over the transition to college and the associations with depression and anxiety symptoms. *J Youth Adolesc* 2015;44(2):389-404. doi: 10.1007/s10964-014-0150-7 [published Online First: 2014/07/19]

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Table 1 Baseline data.

Characteristics	N	%
Gender		
Male	461	43.08
Female	609	56.92
Area		
Nanjing	711	66.45
Non-Nanjing	359	33.55
Education		
Freshman	226	21.12
Sophomore	207	19.35
Junior	215	20.09
Senior	178	16.64
Master	185	17.29
Doctor	59	5.51
Type of major		
Engineering	413	38.60
Medicine	236	22.06
Liberal arts[a]	361	33.74
Other[b]	60	5.61
Cost of living(Chinese Yuan)		
<1000	194	18.13

1000-2000	621	58.04
2000-3000	203	18.97
>3000	52	4.86
Sports time change		
Decrease	444	41.50
No change	379	35.42
Increase	247	23.08

a. Liberal arts include literature, law, and philosophy.

b. Other includes science, agriculture, management, economics, art, education, history, military.

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Table 2 Distribution of screen time and sleep status among different mental health status conditions (depression, anxiety, and loneliness).

Characteristics	Depression[d]			Anxiety[e]			Loneliness	
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P		P
Screen time, h, mean (SD)[b]	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	0.0334[a]	0.2755
Sleep status, n(%)[c]								
Good(N=398)	349 (47.4)	49 (14.7)	<0.001	375 (41.6)	23 (13.7)	<0.001	24.98 (6.40)	<0.001
Bad(N=672)	388 (52.6)	284 (85.3)		527 (58.4)	145 (86.3)		27.42 (6.62)	

a. Spearman's correlation coefficient.

b. SD is standard deviation

c. PSQI score $\geq$ 5 indicates bad sleep status.

d. CES-D score $\geq$ 16 indicates depressive symptoms.

e. GAD-7 score $\geq$ 10 indicates anxiety symptoms.

Table 3 Association of screen time with depression, anxiety, loneliness, and sleep status.

	Depression, OR (95%CI)	Anxiety, OR (95%CI)	Loneliness, β (95%CI)	Sleep status, OR (95%CI)
Crude model				
Screen time, h	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	0.032(-0.091, 0.156)	1.069(1.027, 1.112)**
Adjusted model				
Screen time, h	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	0.107(-0.023, 0.237)	1.049(1.005, 1.095)*

*P < 0.05, **P < 0.01, ***P < 0.001.

Table 4 Mediating effect of sleep status on the association between screen time and mental health status (depression, anxiety, and loneliness).

	Depression, OR (95%CI)				Anxiety, OR (95%CI)			
	X→Y	X+M→Y	Indirect Effect (95%CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95%CI)	Proportion of Mediation (%)
Screen Time, h	1.118 (1.072,1.166)** *	1.115 (1.066, 1.166)***	0.017 (0.016, 0.033) *	13.73%	1.079 (1.023, 0.138)**	1.067 (1.010, 1.128)*	0.016 (0.001, 0.031)*	19.68%
Sleep Status, bad vs. good		5.044 (3.746, 6.793)***				4.449 (2.781,7.117)** *		

*P < 0.05, **P < 0.01, ***P < 0.001.

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Figure 1. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety.

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Sleep Status

Total Effect: 0.1259(p<0.001)
Direce Effect: 0.1086(p<0.001)
Indirect Effect: 0.0173(p=0.031)

Screen time   Depression

(A)

Sleep Status

Total Effect: 0.0808(p=0.004)
Direce Effect: 0.0649(p=0.022)
Indirect Effect: 0.0159(p=0.038)

Screen time   Anxiety

(B)

145x109mm (300 x 300 DPI)

Table S1. Distribution of Screen Time and Sleep Status among Mental Health Status(Depression, Anxiety, Loneliness)

Characteristics	Depression			Anxiety			Loneliness	
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P		P
Screen time, h, mean (SD)	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	0.0334[a]	0.2755
Sleep status, mean (SD)	4.53 (2.37)	6.97 (2.79)	<0.001	5.13 (2.54)	8.08 (3.02)	<0.001	0.2146[a]	<0.001

a.   Spearman's correlation coefficient

b.   Screen Time, Sleep Status and Loneliness are continuous variables

c.   Depression and Anxiety are binary variables

Table S2. Association of Screen time with Depression, Anxiety, Loneliness, and Sleep status

	Depression, OR (95% CI)	Anxiety, OR (95% CI)	Loneliness, β (95% CI)	Sleep status, β (95% CI)
Crude model				
Screen time	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	0.032(-0.091, 0.156)	0.153(0.101, 0.205)***
Adjusted model				
Screen time	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	0.107(-0.023, 0.237)	0.117(1.005, 1.095)***

a.   *p<0.05, **p<0.01, ***p<0.001

Table S3. Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status(Depression, Anxiety, Loneliness)
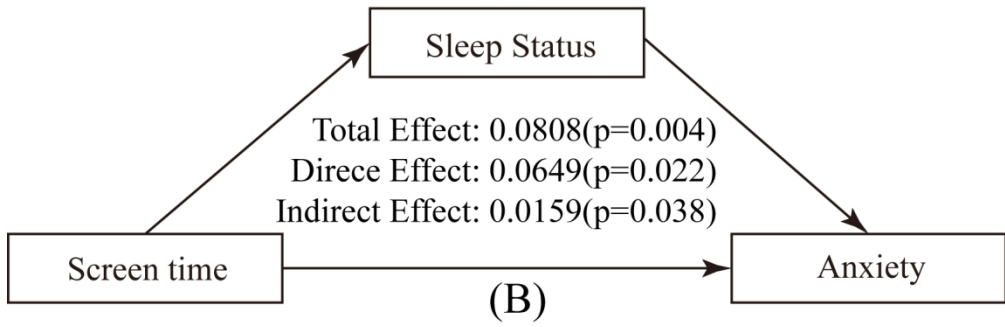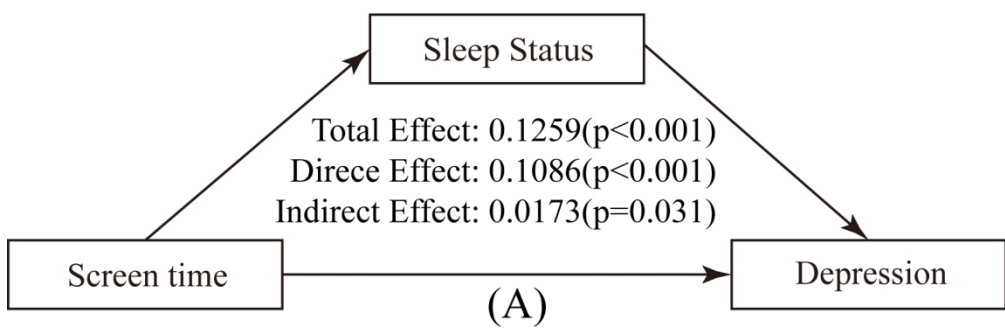
	Depression, OR (95% CI)				Anxiety, OR (95% CI)			
	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)
Screen Time	1.118 (1.072,1.166)***	1.095 (1.045, 1.146)***	0.044 (0.022, 0.066) ***	32.89%	1.079 (1.023, 0.138)**	1.034 (0.973, 1.098)	0.046 (0.023, 0.068)***	57.48%
Sleep Status		1.457 (1.373, 1.547)***				1.477 (1.375, 1.587)***		

a. *p<0.05, **p<0.01, ***p<0.001

Table S4. Distribution of Screen Time and Sleep Status among Mental Health Status(Depression, Anxiety, Loneliness)

Characteristics	Depression			Anxiety			Loneliness		
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P	No(N=463)	Yes(N=607)	P
Screen time, h, mean (SD)	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	8.02 (3.21)	8.19 (3.25)	0.41
Sleep status, mean (SD)	4.53 (2.37)	6.97 (2.79)	<0.001	5.13 (2.54)	8.08 (3.02)	<0.001	4.96 (2.59)	6.08 (2.92)	<0.001

a. Screen Time and Sleep Status are continuous variables

b. Depression, Anxiety and Loneliness are binary variables

Table S5. Association of Screen time with Depression, Anxiety, Loneliness, and Sleep status

	Depression, OR (95% CI)	Anxiety, OR (95% CI)	Loneliness, OR (95% CI)	Sleep status, β (95% CI)
Crude model				
Screen time	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	1.016(0.978,1.055)	0.153(0.101, 0.205)***
Adjusted model				
Screen time	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	1.031(0.989, 1.075)	0.117(1.005, 1.095)***

a. *p<0.05, **p<0.01, ***p<0.001

Table S6. Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status(Depression, Anxiety, Loneliness)

	Depression, OR (95% CI)				Anxiety, OR (95% CI)			
	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)
Screen Time	1.118 (1.072,1.166)***	1.095 (1.045, 1.146)***	0.044 (0.022, 0.066) ***	32.89%	1.079 (1.023, 0.138)**	1.034 (0.973, 1.098)	0.046 (0.023, 0.068)***	57.48%
Sleep Status		1.457 (1.373, 1.547)***				1.477 (1.375, 1.587)***		

a. *p<0.05, **p<0.01, ***p<0.001

Table S7. Distribution of Screen Time and Sleep Status among Mental Health Status(Depression, Anxiety, Loneliness)

Characteristics	Depression			Anxiety			Loneliness		
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P	No(N=463)	Yes(N=607)	P
Screen time, h, mean (SD)	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	8.02 (3.21)	8.19 (3.25)	0.41
Sleep status, n(%)									
Good(N=398)	349(47.4%)	49 (14.7%)	<0.001	375(41.6%)	23(13.7%)	<0.001	216(46.7%)	182(30.0%)	<0.001
Bad(N=672)	388(52.6%)	284 (85.3%)		527(58.4%)	145 (86.3%)		247(53.3%)	425(70.0%)	

a. Screen Time is continuous variable

b. Depression, Anxiety, Loneliness and Sleep Status are binary variables

Table S8. Association of Screen time with Depression, Anxiety, Loneliness, and Sleep status

	Depression, OR (95% CI)	Anxiety, OR (95% CI)	Loneliness, OR (95% CI)	Sleep status, OR (95% CI)
Crude model				
Screen time	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	1.016(0.978,1.055)	1.069(1.027, 1.112)**
Adjusted model				
Screen time	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	1.031(0.989, 1.075)	1.049(1.005, 1.095)*

a. *p<0.05, **p<0.01, ***p<0.001

Table S9. Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status(Depression, Anxiety, Loneliness)

	Depression, OR (95% CI)				Anxiety, OR (95% CI)			
	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)
Screen Time	1.118 (1.072,1.166)***	1.115 (1.066, 1.166)***	0.017 (0.016, 0.033) *	13.73%	1.079 (1.023, 0.138)**	1.067 (1.010, 1.128)*	0.016 (0.001, 0.031)*	19.68%
Sleep Status		5.044 (3.746, 6.793)***				4.449 (2.781,7.117)***		

a. *p<0.05, **p<0.01, ***p<0.001

Figure 1. Flow chart of questionnaire screening.
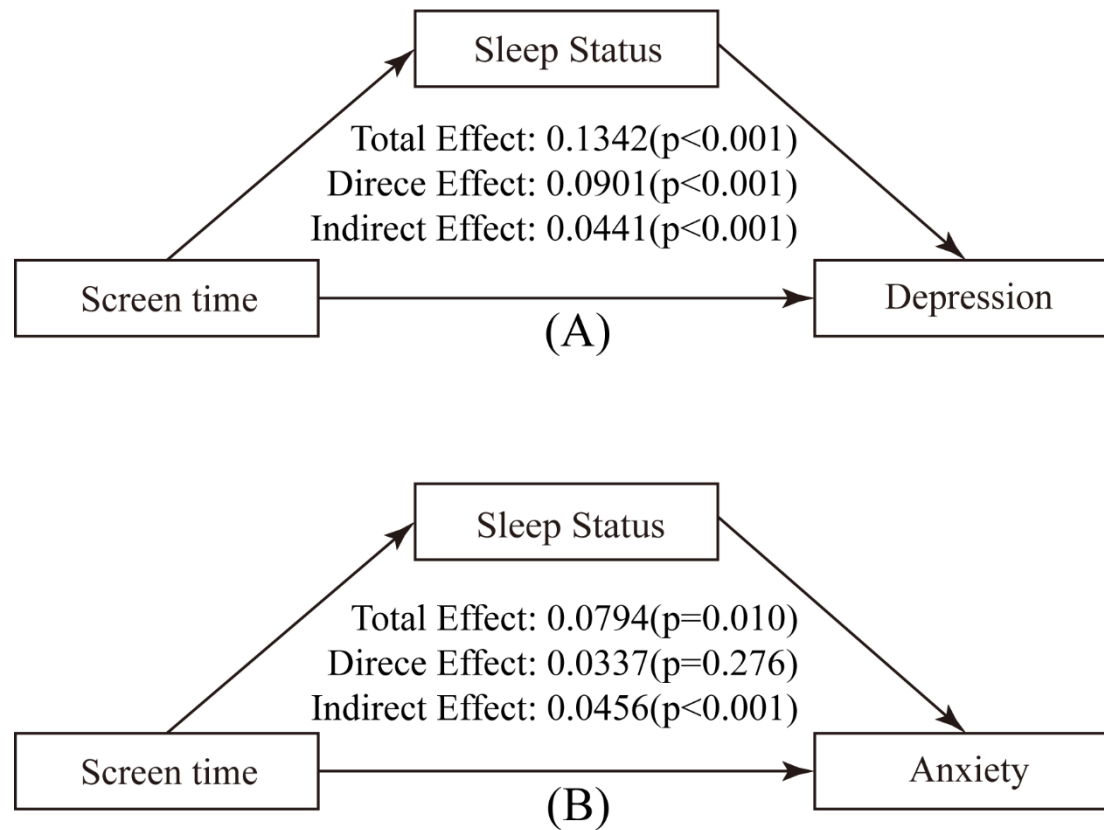
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Figure S2. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety.

Figure S3. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety.
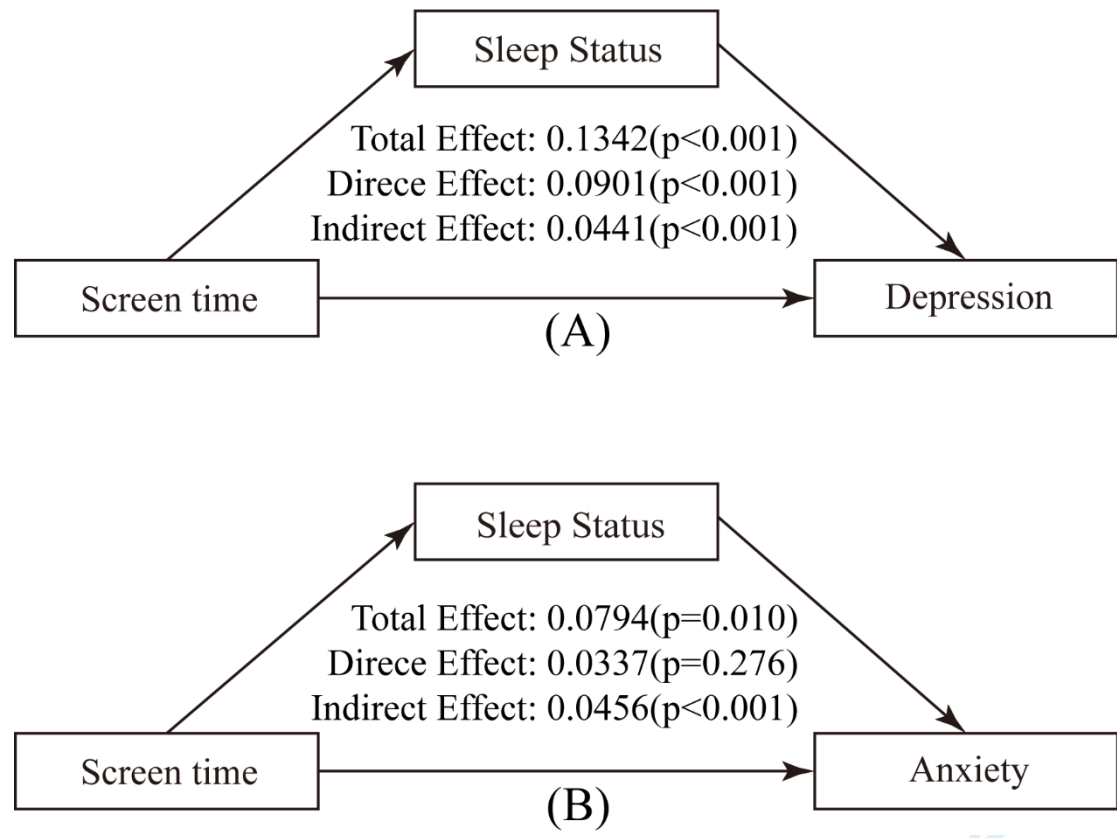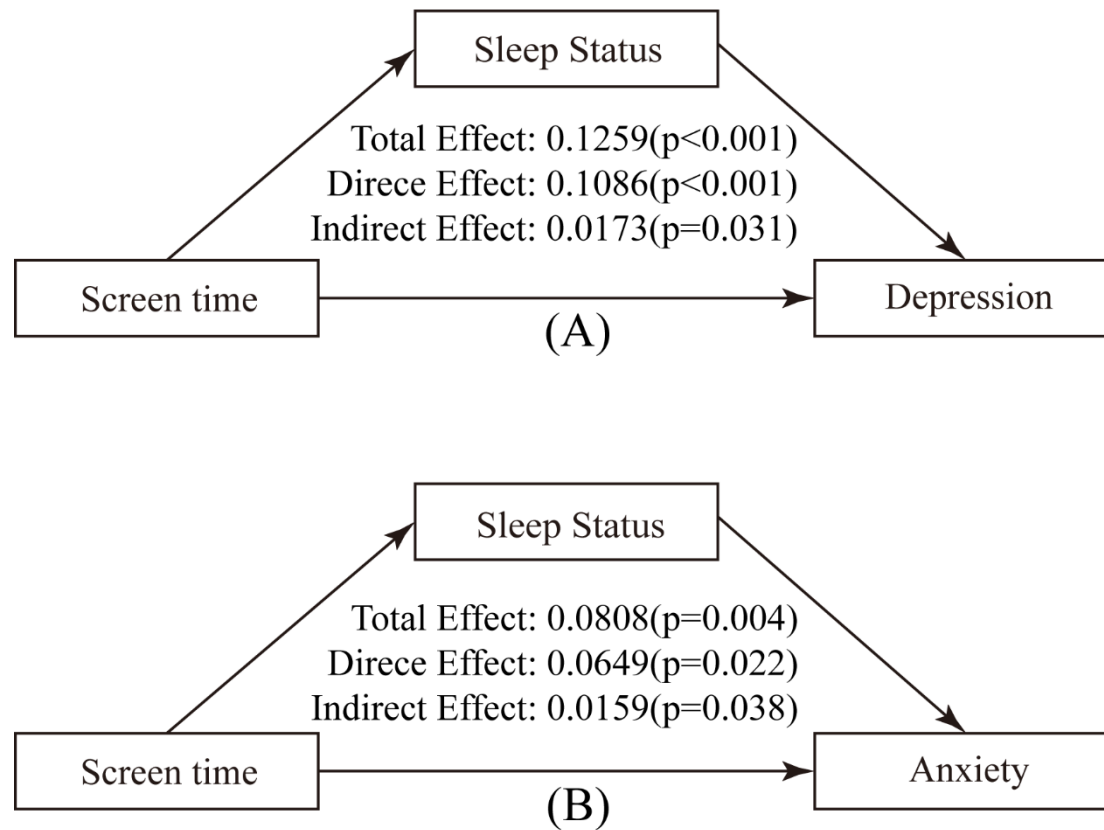
Figure S4. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety.

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5,6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5,6*
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6,7
		(*b*) Describe any methods used to examine subgroups and interactions	6,7
		(*c*) Explain how missing data were addressed	6,7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6,7
		(*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure S1
		(b) Give reasons for non-participation at each stage	Figure S1
		(c) Consider use of a flow diagram	Figure S1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	16
		(b) Indicate number of participants with missing data for each variable of interest	16
Outcome data	15*	Report numbers of outcome events or summary measures	17

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	18
		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	17
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8

Discussion

Key results	18	Summarise key results with reference to study objectives	7,8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9,10
Generalisability	21	Discuss the generalisability (external validity) of the study results	11

Other information

| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 11 |

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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The Relationship Between Mental Health, sleep status and Screen Time Among University Students During the COVID-19 Pandemic: a cross-sectional study

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The Relationship Between Mental Health, sleep status and Screen Time Among University Students During the COVID-19 Pandemic: a cross-sectional study

Wei Wang[#], Jingfeng Jiang[#]*, Lerong Qi, Fanqi Zhao, Jingying Wu, Xiaoqi Zhu, Bei Wang, Xiang Hong*

1. Key Laboratory of Environmental Medicine and Engineering of Ministry of Education, Department of Epidemiology and Health Statistics, School of Public Health, Southeast University, Nanjing, Jiangsu, China
2. Wuxi Center for Disease Control and Prevention

[#] These authors contributed equally to this work and should be considered co-first authors.

* Corresponding author: Xiang Hong, 87#, Dingjiaqiao Road, Gulou District, Nanjing City, Jiangsu Province, China. 210009. Email: hongxiang@seu.edu.cn

Jingfeng Jiang, 499 Jincheng Road, Liangxi District, Wuxi City, Jiangsu Province, China. Email: jjf870122@163.com

Abstract

Objective: On July 20, 2021, after the outbreak of COVID-19 at Nanjing Lukou International Airport, several universities started closed management and online teaching. This had a large impact on students' daily life and study, which may lead to mental health problems. The purpose of this study is to study the effect of screen time on mental health status of university students and the possible mediating effect of sleep status.

Methods: This was a cross-sectional study. A web-based questionnaire survey was employed that included demographic characteristics, sleep status, and mental health status (depression, anxiety, and loneliness). The Pittsburgh Sleep Quality Index scale was used to assess sleep status, while the Center for Epidemiologic Studies Depression (CES-D) scale, Generalized Anxiety Disorder-7 (GAD-7) scale, and Emotional versus Social Loneliness Scale (ESLS) were used to assess depression, anxiety, and loneliness, respectively. Linear and logistic regression models were developed and adjusted for confounding factors, and finally the mediating effects were tested using the Karlson-Holm-Breen (KHB) method.

Results: Finally, 1070 valid questionnaires were included. Among these, 604 (56.45%) indicated depressive symptoms (CES-D score $\geq$ 16) and 902 (84.30%) indicated anxiety symptoms (GAD-7 score $\geq$ 10). The mean ESLS score (for loneliness) was 26.51 ± 6.64. The relationship between screen time and depressive symptoms (OR = 1.118, 95% CI = 1.072–1.166) and anxiety symptoms (OR = 1.079, 95% CI = 1.023–1.138) remained significant after adjusting for confounding factors. Meanwhile, sleep status plays an intermediary role in screen time and mental health status (depression and anxiety) and accounts for 13.73% and 19.68% of the total effects, respectively. We did not find a significant association between screen time and loneliness.

Conclusion: During the outbreak of COVID-19, screen time is inevitably prolonged among university students. There is a relationship between mental health and screen time, and sleep status plays a mediating role.

Keywords: screen time; sleep status; depression; anxiety; loneliness

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Strengths and limitations of this study

The first multi-angle study of screen time, sleep status, and mental health status of college students

during the COVID-19 pandemic including mediation effects.

Internationally recognized scales were used to estimate mental health, so the results are comparable

to those of other studies.

The potential confounding factors were adjusted for and Multiple sensitivity analyses were

conducted, so the results are robust.

This is a cross-sectional study, which is weak in causal inference and has the risk of reverse causality.

Due to the use of online questionnaire, there may be selection bias and information bias.

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1 Introduction

On July 20th, 2021, nine Nanjing Lukou International Airport staff tested positive for SARS-CoV-2.(1) The government has sought to contain the spread of COVID-19 through lockdowns, limiting travel, and restrict people to maintain distance. Many parts of Nanjing have been designated as risk or control areas, and several universities have implemented measures such as closed management and online teaching. In this context, COVID-19 also has a significant impact on mental health.(2-4) University students are at an important transition stage in their lives and face a unique set of challenges. Therefore, there is a need to pay attention to the impact of the COVID-19 pandemic on the mental health of university students. Some studies have shown that the psychological pressure on college students caused by COVID-19 is particularly prominent in different age groups.(5, 6) During the pandemic, screen time is inevitably prolonged among students, and little is known about the exact impact of the COVID-19 pandemic on the mental health of university students.

When universities carry out closed management, the screen time of university students is bound to be extended. Screen time is divided into several areas, such as studying and working, browsing news, and socializing. Excessive screen time can affect adolescents' brain function and cognitive ability.(7) The consequences of increased screen time in the wake of the pandemic have been analyzed. A study from China concluded that screen time (specifically, time spent studying) is negatively associated with mood status,(8) and another study concluded that screen time is correlated with the severity of depression and anxiety.(9) Excessive screen time can also lead to increased feelings of loneliness(5). Some studies suggest that outdoor activity or exposure to nature (green time) may diminish the effects of increased screen time,(10, 11) but apparently, green time does not increase when university students are in closed management.

Lack of sleep affects the physical and mental health and psychosocial function of young people. Studies suggest that excessive screen time can lead to a lack of sleep in different ways: Screen time can replace sleep time;(12) the strong light emitted by electronic devices before going to bed can inhibit the production of melatonin and cause circadian rhythm disorder;(13) and teenagers using social media before going to bed not only shorten their sleep time,(14) but are also awakened by notifications at night.(15) Sleep problems are often accompanied by mental health problems such as depression and anxiety, and are even used as predictors of psychological problems.(16) Therefore,

we put forward the hypothesis that screen time can affect the mental health of university students, and sleep status plays an intermediary role.

2 Materials and Methods

2.1 Study Design and Sample

This cross-sectional study was conducted from August 1 to September 31, 2021. The participants were university students studying in China, aged 18–30 years, with no requirements on gender and major. The questionnaire was distributed online and widely disseminated after the pre-experiment, the questionnaires were created and posted on forums and social media through WenJuanxing software(https://www.wjx.cn/). The process of estimating the sample size for this study is described in the Supplementary Material-Sample size estimation, after estimation a total of 1200 questionnaires were distributed and 1070 valid questionnaires were finally included, with a validity rate of 89.2%, the detailed questionnaire selection process is shown in Figure S1.

The survey was completely anonymous. The purpose of the study was detailed in the questionnaire guidelines. Informed consent was provided by all participants. Permissions for the questionnaire were set (every IP address can only be used once) to prevent duplication. All questions in the questionnaire were set as required fields to ensure data integrity. This study was approved by the Ethics Committee of Zhongda Hospital, Southeast University.

2.2 Measures

2.2.1 Screen Time

Screen time is defined as the total time spent per day in front of a screen of any electronic device, including mobile phones, tablets, and e-books. Screen time is divided into four parts according to the purpose of the screen time: work and study, social activities, audio-visual entertainment, and shopping and takeaway, we defined the different screen times categorizations in detail in the questionnaire to avoid bias. These classifications are reported by the respondents themselves. In the present study, 18 questionnaires reporting a total of more than 24 hours of screen time per day were excluded (Figure S1).

2.2.2 Sleep Status

Sleep status was assessed using the Pittsburgh Sleep Quality Index (PSQI), a 19-item scale subdivided into seven parts, i.e., (i) sleep duration, (ii) sleep disturbance, (iii) sleep latency, (iv)

daytime dysfunction due to sleepiness, (v) sleep efficiency, (vi) overall sleep quality, and (vii) sleep medication use,(17) with a score of 0–3 for each section and thus a maximum total score of 21. A total score of 5 is often used as the critical value to judge sleep status,(18-20) where PSQI < 5 is considered good sleep quality and PSQI ≥ 5 is considered bad sleep quality.

2.2.3 Mental Health Status

In the present study, mental health status was assessed based on depression, anxiety, and loneliness.

Depression was assessed using the Center for Epidemiologic Studies Depression (CES-D) scale,(21) which is a brief self-report scale containing 20 items with a maximum total score of 60. CES-D ≥ 16 is generally considered to indicate depressive symptoms.(22-24)

Anxiety was assessed with the Generalized Anxiety Disorder-7 (GAD-7) scale,(25) which is also a self-rating scale. The scale has seven items, each with a score of 0–3 points, reaching a maximum total score of 21 points. A GAD-7 score of ≥ 10 is generally considered to indicate anxiety symptoms.

The Emotional versus Social Loneliness Scale (ESLS)(26) was used to evaluate loneliness. The ESLS utilizes 10 items to evaluate emotional and social loneliness on a scale of 0–5 for each question, with higher scores indicating more intense loneliness.

2.2.4 Covariates

General demographic characteristics and exercise status were included as covariates. General demographic characteristics included: gender, region (Nanjing, non-Nanjing), education (Bachelor Candidate, Master candidate, PhD candidate), type of major (engineering, medicine, liberal arts, other), cost of living (<1000, 1000–2000, 2000–3000, >3000 yuan) and change in sports time (decrease, no change, increase) between before and after the COVID-19 outbreak.

2.3 Statistical Analysis

A database with all collected questionnaire data was created. The total scores were calculated and invalid data were eliminated. Continuous variables are presented as mean and standard deviation after passing the normality test, and categorical variables are presented as absolute values and proportions. The *t*-test, chi-square test, or Spearman's coefficient test was selected for correlation analysis between variables. The relationships between independent and dependent variables and between independent and mediating variables were examined using logistic regression

models (results for dichotomous variables) or linear regression models (results for continuous variables). Two models were developed to account for possible confounders: a crude model without adjusting for any confounders and an adjusted model controlling for differences in gender, region, education level, type of profession, cost of living, and time spent doing exercise. After controlling for confounding factors, we also further tested whether the relationship between screen time and mental health status changed when the mediating variable (sleep status) was included. Finally, because the mediating variable was dichotomous and the dependent variable had dichotomous and continuous variables, we used the Karlson-Holm-Breen (KHB) method(27) to calculate the model's total, direct, and indirect effects. We considered a profile effect significant if its confidence interval (CI) did not include zero. All statistical analyses were conducted by STATA version 17.0 (Stata Corp, College Station, TX).

2.4 Patient and public involvement

The study participants were not involved in the design of this study.

3 Result

3.1 Participant characteristics

In total, 1070 participants were included. The demographic characteristics of the study population are shown in Table 1. Males accounted for 43.08%, the number of undergraduate students was the largest (826, 77.20%), engineering students accounted for 38.60%, most people's cost of living was in the range of 1000–2000 yuan, accounting for 58.04%, and after the emergence of the pandemic, 76.92% of university students had the same or reduced exercise time. The distribution of screen time and sleep status across mental health conditions is given in Table 2. Worse psychological conditions such as depressive symptoms and anxiety symptoms were associated with longer screen time (depression: 7.79 h vs. 8.83 h, $P < 0.001$; anxiety: 7.98 h vs. 8.85 h, $P = 0.001$), but similar results were not observed for loneliness symptoms. Poor sleep status tended to be associated with poor mental health status, as did loneliness symptoms. The proportions of people with good sleep and bad sleep are different across mental health conditions (without depression: 47.4% vs. 52.6%; with depression: 14.7% vs. 85.3%; without anxiety: 41.6% vs. 58.4%; with anxiety: 13.7% vs. 86.3%). The loneliness score was also lower among people with good sleep than among people with bad sleep (24.98 vs. 27.42, $P < 0.001$).

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3.2 Association of Screen Time with Sleep Status and Mental Health Status

Table 3 shows the relationship between screen time and mental health status. In the crude model without adjusting for any confounder, longer screen time was significantly associated with depressive symptoms and anxiety symptoms (depression: odds ratio [OR] = 1.107, 95% CI = 1.065–1.151; anxiety: OR = 1.084, 95% CI = 1.032–1.139), but not with loneliness status (β = 0.032, 95% CI = −0.091 to 0.156). After adjusting for potential confounding factors such as cost of living and changes in exercise time, the relationship between screen time and depressive symptoms (OR = 1.118, 95% CI = 1.072–1.166) and anxiety symptoms (OR = 1.079, 95% CI = 1.023–1.138) remained significant, while the relationship between screen time and loneliness symptoms remained not statistically significant (β = 0.106, 95% CI = −0.023 to 0.237). Table 3 also shows that increased screen time is a risk factor for sleep status in both the unadjusted crude model (OR = 1.069, 95% CI = 1.027–1.112) and the model after adjusting for confounding factors (OR = 1.049, 95% CI = 1.005–1.095).

3.3 Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status

The mediation effect of sleep status between screen time and mental health status (depression and anxiety) is shown in Table 4. After controlling for screen time ($P < 0.05$) and other covariates, poor sleep status was a risk factor for depressive symptoms (OR = 5.044, 95% CI = 3.746–6.793) and anxiety symptoms (OR = 4.449, 95% CI = 2.781–7.117). The relationship between increased screen time and depressive symptoms (OR = 1.115, 95% CI = 1.066–1.166) and anxiety symptoms (OR = 1.067, 95% CI = 1.010–1.128) remained significant after the inclusion of mediating variables in the model.

The analysis of mediation effects showed that screen time had a significant indirect effect on both depressive symptoms (indirect effect = 0.0173, $P < 0.05$) (Figure 1A) and anxiety symptoms (indirect effect = 0.0076, $P < 0.05$) (Figure 1B) through sleep status after controlling for all covariates. As demonstrated in Table 4, the relative proportions of intermediaries are 13.73% and 19.68%, respectively.

3.4 Sensitivity Analysis

To ensure robustness of the results, we repeated the above analysis after transformation of variables. The results are presented in the Supplementary Material. As shown in Tables S1–S6 and

Figure S2-S3, when we used the PSQI score as a continuous variable to indicate sleep status, the mediating effect of sleep status between screen time and depressive symptoms and between screen time and anxiety symptoms was increased (depression: indirect effect = 0.044, 95% CI = 0.022–0.066, proportion of mediation = 32.89%; anxiety: indirect effect = 0.046, 95% CI = 0.023–0.068, proportion of mediation = 57.48%). As shown in Tables S7–S9 and Figure S4, no association was found between screen time and loneliness symptoms, either using the ESLS score as a continuous variable to represent loneliness symptoms or using loneliness symptoms as a dichotomous variable according to the median ESLS score (median = 26).

4 Discussion

In the present study, we investigated the relationship between screen time, sleep status, and mental health status among university students. The study was conducted shortly after the COVID-19 outbreak at Nanjing Lukou International Airport. We focused on the effects of university closure on students. Our study showed that among university students, screen time was associated with depression and anxiety. No significant relationship between screen time and loneliness was observed. Sleep status partially mediated the effects of screen time on depression and anxiety. This survey was conducted among university students during a COVID-19 outbreak to provide suggestions for healthy care measures at universities during outbreaks.

Logistic regression analysis showed that after adjusting for confounding effects, the proportions of students with depressive symptoms and with anxiety symptoms were higher among university students with long screen time. Several studies conducted in China and abroad have shown that excessive screen time is positively associated with mental health status among university students.(28-32) As for the reason for this correlation, some researchers believe that during COVID-19 outbreaks, we get a lot of negative information through electronic media, but the quality of such information is uncontrollable. In addition, fragmented information is prevalent, which leads to an increase in our negative emotions and possibly also to symptoms of depression and anxiety.(33-36) In public health emergencies, negative information can be amplified with the influx of information, resulting in more serious consequences.(37) Organized sports are one of the most common forms of physical activity for teens, but they are also eliminated during COVID-19, and using a screen to connect with friends and family is the only option.(38) In addition, studies have found that longer

screen time in adolescents is associated with a decreased attention span,(39) violent tendencies,(40) and low self-esteem,(41) all of which are proven risk factors for mental health conditions.(42)

The results also showed that screen time and sleep status were negatively correlated, and sleep status partially mediated the relationship between screen time and both depression and anxiety, accounting for 13.73% and 19.68% of the total effects, respectively. Excessive screen time may affect melatonin secretion(13) and sleep is also affected by nighttime notifications.(15) In addition, video games may lead to mental arousal and thus affect sleep,(43) and the violent content of video games has a particularly pronounced effect on sleep conditions.(44) University students are often surrounded by a large number of electronic devices, especially in places such as dormitories where the division of areas is not clear, and the hindrance to their sleep is very obvious.(45) In addition, even if the screen is turned off, electromagnetic radiation may still be perceived as light by the pineal gland, thus affecting the secretion of melatonin and causing sleep difficulties.(46) Sleep status was included in the present study because sleep status affects physical and psychological functions in young people, including anxiety and depression,(47) which may be related to poor sleep, dysfunction of the cholinergic neurotransmitter system and the prefrontal cortex, and increased limbic system activity.(48) Moreover, sleep disorders can cause abnormal hormone secretion by interfering with the function of the hypothalamus–pituitary–adrenal axis, which may make the body more sensitive to stress factors in the environment and may induce psychological problems.(49) Screen time also has adverse effects on early childhood neurodevelopment. For example, children with longer screen time have significantly lower communication and daily living skill scores.(50)

The present study has several strengths. First, this study is the first multi-angle study of screen time, sleep status, and mental health status of college students during the COVID-19 pandemic including mediation effects. This is of great significance for the formulation of epidemic prevention and control strategies. Second, we used internationally recognized scales to estimate the mental health status, so the results are comparable with those of other studies. Third, the potential confounding factors were adjusted for and multiple sensitivity analyses were conducted, so the results are robust.

However, there were still some limitations in this study that need to be carefully considered. First, this is a cross-sectional study, which is weak in causal inference and has the risk of reverse causality. Second, the online questionnaire survey may result in selection bias and information bias.

Third, the evaluation of some covariates is not accurate, such as the change in sports time. More accurate indicators to evaluate exercise should be considered, such as the International Physical Activity questionnaire.(51) Fourth, there is the possibility of bias due to unmeasured confounding factors, such as the study subjects' living habits and personality. Finally, insomnia may also lead to increased screen time, with potential reverse causality needing to be explored in further longitudinal studies.

In the context of COVID-19 prevention and control, the prolonged use of electronic devices by university students is unavoidable, While the impact of increased screen time on mental health status can be mitigated by improving sleep quality, But how to improve sleep conditions is a question worthy of attention, Reducing alcohol and caffeine intake, following a regular bedtime and engaging in meditation practices are more effective ways to improve sleeping conditions.(52) Schools and universities should also provide health care measures to ensure the physical and mental health of students. A longitudinal study should be conducted in the future to further investigate the association between screen time and mental health status.

5 Conclusion

At the time of the short-term outbreak of COVID-19, our findings suggest that the after controlling for confounding factors, increased screen time among university students was found to be positively associated with depressive symptoms and anxiety symptoms. Sleep status plays a partially mediating role. Although the COVID-19 pandemic is over, this finding remains potentially valuable and informative in the event of a similar widespread public health event.

Author contribution statement

Xiang Hong: Conceptualization, Funding Acquisition, Methodology and Supervision; Wei Wang and Jingfeng Jiang: Data Curation, Software, Formal Analysis and Writing – Original Draft; Lerong Qi, Fanqi Zhao, Jingying Wu, and Xiaoqi Zhu: Investigation and Validation; Bei Wang: Project Administration and Writing – Review & Editing.

Declaration of interests statement

The authors declare no conflict of interest.

Data availability statement

Data are available upon reasonable request. The data set can be made available to researchers.

Ethics approval

This study involves human participants and was approved by Ethics Committee of Zhongda Hospital, Southeast University(2022ZDKYSB013). Informed consent was provided by all participants.

References

1. LIU Y, YANG B, LIU L, JILILI M, YANG A. Occupational Characteristics in the Outbreak of the COVID-19 Delta Variant in Nanjing, China: Rethinking the Occupational Health and Safety Vulnerability of Essential Workers. Int J Environ Res Public Health. 2021 Oct 13;18.

2. CAMPION J, JAVED A, SARTORIUS N, MARMOT M. Addressing the public mental health challenge of COVID-19. The Lancet Psychiatry. 2020;7:657-9.

3. SERAFINI G, PARMIGIANI B, AMERIO A, AGUGLIA A, SHER L, AMORE M. The psychological impact of COVID-19 on the mental health in the general population. QJM. 2020 Jun 22.

4. GARFIN DR, SILVER RC, HOLMAN EA. The novel coronavirus (COVID-2019) outbreak: Amplification of public health consequences by media exposure. Health Psychol. 2020 May;39:355-7.

5. LISITSA E, BENJAMIN KS, CHUN SK, et al. Loneliness among young adults during COVID-19 pandemic: The mediational roles of social media use and social support seeking. 2020;39:708-26.

6. BROWNING M, LARSON LR, SHARAIEVSKA I, et al. Psychological impacts from COVID-19 among university students: Risk factors across seven states in the United States. PLoS One. 2021;16:e0245327.

7. YU L, ZHOU X. Emotional Competence as a Mediator of the Relationship Between Internet Addiction and Negative Emotion in Young Adolescents in Hong Kong. Applied Research in Quality of Life. 2021;16:2419-38.

8. XIAO S, YAN Z, ZHAO L. Physical Activity, Screen Time, and Mood Disturbance Among Chinese Adolescents During COVID-19. J Psychosoc Nurs Ment Health Serv. 2021 Apr;59:14-20.

9. MARAS D, FLAMENT MF, MURRAY M, et al. Screen time is associated with depression and anxiety in Canadian youth. Prev Med. 2015 Apr;73:133-8.

10. WU X, TAO S, ZHANG Y, ZHANG S, TAO F. Low physical activity and high screen time can increase the risks of mental health problems and poor sleep quality among Chinese college students. PLoS One. 2015;10:e0119607.

11. OSWALD TK, RUMBOLD AR, KEDZIOR SGE, KOHLER M, MOORE VM. Mental Health of Young Australians during the COVID-19 Pandemic: Exploring the Roles of Employment Precarity, Screen Time, and Contact with Nature. Int J Environ Res Public Health. 2021 May 25;18.

12. CHEUNG CH, BEDFORD R, SAEZ DE URABAIN IR, KARMILOFF-SMITH A, SMITH TJ. Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. Sci Rep. 2017 Apr 13;7:46104.

13. FIGUEIRO M, OVERINGTON D. Self-luminous devices and melatonin suppression in adolescents. Lighting Research & Technology. 2015 2016/12/01;48:966-75.

14. GROVER K, PECOR K, MALKOWSKI M, et al. Effects of Instant Messaging on School Performance in Adolescents. 2016;31:850-7.

15. FALBE J, DAVISON KK, FRANCKLE RL, et al. Sleep Duration, Restfulness, and Screens in the Sleep Environment. Pediatrics. 2015;135:e367-e75.

16. MARINELLI M, SUNYER J, ALVAREZ-PEDREROL M, et al. Hours of television viewing and sleep duration in children: a multicenter birth cohort study. JAMA Pediatr. 2014 May;168:458-64.

17. BUYSSE DJ, REYNOLDS CF, 3RD, MONK TH, BERMAN SR, KUPFER DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res. 1989 May;28:193-213.

18. BERTOLAZI AN, FAGONDES SC, HOFF LS, et al. Validation of the Brazilian Portuguese version of the Pittsburgh Sleep Quality Index. Sleep Med. 2011 Jan;12:70-5.

19. BARAZZETTI L, GARCEZ A, FREITAS SANT'ANNA PC, SOUZA DE BAIRROS F, DIAS-DA-COSTA JS, ANSELMO OLINTO MT. Does sleep quality modify the relationship between common mental disorders and chronic low back pain in adult women? Sleep Med. 2022 Aug;96:132-9.

20. HALSON SL, JOHNSTON RD, APPANEAL RN, et al. Sleep Quality in Elite Athletes: Normative Values, Reliability and Understanding Contributors to Poor Sleep. Sports Med. 2022 Feb;52:417-26.

21. RADLOFF LSJAPM. The CES-D scale: A self-report depression scale for research in the general population. 1977;1:385-401.

22. COSTANTINE MM, SMITH K, THOM EA, et al. Effect of Thyroxine Therapy on Depressive Symptoms Among Women With Subclinical Hypothyroidism. Obstet Gynecol. 2020 Apr;135:812-20.

23. LI Z, HICKS MH. The CES-D in Chinese American women: construct validity, diagnostic validity for major depression, and cultural response bias. Psychiatry Res. 2010 Feb 28;175:227-32.

24. VILAGUT G, FORERO CG, BARBAGLIA G, ALONSO J. Screening for Depression in the General Population with the Center for Epidemiologic Studies Depression (CES-D): A Systematic Review with Meta-Analysis. PLoS One. 2016;11:e0155431.

25. SPITZER RL, KROENKE K, WILLIAMS JB, LöWE B. A brief measure for assessing generalized anxiety disorder: the GAD-7. Archives of internal medicine. 2006 May 22;166:1092-7.

26. SHAVER PR, BRENNAN KAJMPSPA. Measures of depression. 1991;1:195-289.

27. KOHLER U, KARLSON KB, HOLM AJTSJ. Comparing coefficients of nested nonlinear probability models. 2011;11:420-38.

28. FENG Q, ZHANG QL, DU Y, YE YL, HE QQ. Associations of physical activity, screen time with depression, anxiety and sleep quality among Chinese college freshmen. PLoS One. 2014;9:e100914.

29. LI X, VANDERLOO LM, KEOWN-STONEMAN CDG, et al. Screen Use and Mental Health Symptoms in Canadian Children and Youth During the COVID-19 Pandemic. JAMA Netw Open. 2021 Dec 1;4:e2140875.

30. LIU M, WU L, YAO S. Dose-response association of screen time-based sedentary behaviour in children and adolescents and depression: a meta-analysis of observational studies. Br J Sports Med. 2016 Oct;50:1252-8.

31. WANG W, DU X, GUO Y, et al. Associations Among Screen Time, Sleep Duration and Depressive Symptoms Among Chinese Adolescents. J Affect Disord. 2021 Apr 1;284:69-74.

32. ZHANG Y, WU X, TAO S, et al. Associations between screen time, physical activity, and depressive symptoms during the 2019 coronavirus disease (COVID-19) outbreak among Chinese college students. Environ Health Prev Med. 2021 Nov 2;26:107.

33. CHAO M, XUE D, LIU T, YANG H, HALL BJ. Media use and acute psychological outcomes during COVID-19 outbreak in China. J Anxiety Disord. 2020 Aug;74:102248.

34. DUBEY S, BISWAS P, GHOSH R, et al. Psychosocial impact of COVID-19. Diabetes Metab Syndr. 2020 Sep - Oct;14:779-88.

35. HOLMAN EA, GARFIN DR, SILVER RC. Media's role in broadcasting acute stress following the Boston Marathon bombings. Proc Natl Acad Sci U S A. 2014 Jan 7;111:93-8.

36. RESNYANSKY L. Social Media, Disaster Studies, and Human Communication. IEEE Technology and Society Magazine. 2014;33:54-65.

37. QIN F, SONG Y, NASSIS GP, et al. Prevalence of insufficient physical activity, sedentary screen time and emotional well-being during the early days of the 2019 novel coronavirus (COVID-19) outbreak in China: a national cross-sectional study. 2020.

38. CHAMPION KE, NEWTON NC, GARDNER LA, et al. Health4Life eHealth intervention to

modify multiple lifestyle risk behaviours among adolescent students in Australia: a cluster-randomised controlled trial. Lancet Digit Health. 2023 May;5:e276-e87.

39. TAMANA SK, EZEUGWU V, CHIKUMA J, et al. Screen-time is associated with inattention problems in preschoolers: Results from the CHILD birth cohort study. PLoS One. 2019;14:e0213995.

40. KEIKHA M, QORBANI M, KAZEMI TABAEE MS, DJALALINIA S, KELISHADI R. Screen Time Activities and Aggressive Behaviors Among Children and Adolescents: A Systematic Review. Int J Prev Med. 2020;11:59.

41. BRAIG S, GENUNEIT J, WALTER V, et al. Screen Time, Physical Activity and Self-Esteem in Children: The Ulm Birth Cohort Study. Int J Environ Res Public Health. 2018 Jun 16;15.

42. GRONTVED A, SINGHAMMER J, FROBERG K, et al. A prospective study of screen time in adolescence and depression symptoms in young adulthood. Prev Med. 2015 Dec;81:108-13.

43. KING DL, DELFABBRO PH, ZWAANS T, KAPTSIS D. Sleep Interference Effects of Pathological Electronic Media Use during Adolescence. International Journal of Mental Health and Addiction. 2013;12:21-35.

44. OSHIMA N, NISHIDA A, SHIMODERA S, et al. The suicidal feelings, self-injury, and mobile phone use after lights out in adolescents. J Pediatr Psychol. 2012 Oct;37:1023-30.

45. HYSING M, PALLESEN S, STORMARK KM, JAKOBSEN R, LUNDERVOLD AJ, SIVERTSEN B. Sleep and use of electronic devices in adolescence: results from a large population-based study. BMJ Open. 2015 Feb 2;5:e006748.

46. HALGAMUGE MN. Pineal melatonin level disruption in humans due to electromagnetic fields and ICNIRP limits. Radiat Prot Dosimetry. 2013 May;154:405-16.

47. O'BRIEN LMJSMC. The neurocognitive effects of sleep disruption in children and adolescents. 2011;6:109-16.

48. RANITI MB, ALLEN NB, SCHWARTZ O, et al. Sleep duration and sleep quality: associations with depressive symptoms across adolescence. 2017;15:198-215.

49. VAN DALFSEN JH, MARKUS CRJSMR. The influence of sleep on human hypothalamic–pituitary–adrenal (HPA) axis reactivity: A systematic review. 2018;39:187-94.

50. MIURA M, TANIMOTO T. Study Inclusions in the Association Between Screen Time and Neurodevelopment in Early Childhood. JAMA Pediatr. 2023 Jul 1;177:738-9.

51. DOANE LD, GRESS-SMITH JL, BREITENSTEIN RS. Multi-method assessments of sleep over the transition to college and the associations with depression and anxiety symptoms. J Youth Adolesc. 2015 Feb;44:389-404.

52. BARANWAL N, YU PK, SIEGEL NS. Sleep physiology, pathophysiology, and sleep hygiene. Prog Cardiovasc Dis. 2023 Mar-Apr;77:59-69.

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Table 1 Baseline data.

Characteristics	N	%
Gender		
Male	461	43.08
Female	609	56.92
Area		
Nanjing	711	66.45
Non-Nanjing	359	33.55
Education		
Freshman	226	21.12
Sophomore	207	19.35
Junior	215	20.09
Senior	178	16.64
Master candidate	185	17.29
PhD candidate	59	5.51
Type of major		
Engineering	413	38.60
Medicine	236	22.06
Liberal arts[a]	361	33.74
Other[b]	60	5.61
Cost of living(Chinese Yuan)		
<1000	194	18.13

1000-2000	621	58.04
2000-3000	203	18.97
>3000	52	4.86
Sports time change		
Decrease	444	41.50
No change	379	35.42
Increase	247	23.08

a. Liberal arts include literature, law, and philosophy.

b. Other includes science, agriculture, management, economics, art, education, history, military.

Table 2 Distribution of screen time and sleep status among different mental health status conditions (depression, anxiety, and loneliness).

Characteristics	Depression[d]			Anxiety[e]			Loneliness	
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P		P
Screen time, h, mean (SD)[b]	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	0.0334[a]	0.2755
Sleep status, n(%)[c]								
Good(N=398)	349 (47.4)	49 (14.7)	<0.001	375 (41.6)	23 (13.7)	<0.001	24.98 (6.40)	<0.001
Bad(N=672)	388 (52.6)	284 (85.3)		527 (58.4)	145 (86.3)		27.42 (6.62)	

a. Spearman's correlation coefficient.

b. SD is standard deviation

c. PSQI score $\geq$ 5 indicates bad sleep status.

d. CES-D score $\geq$ 16 indicates depressive symptoms.

e. GAD-7 score $\geq$ 10 indicates anxiety symptoms.

Table 3 Association of screen time with depression, anxiety, loneliness, and sleep status.

	Depression, OR (95%CI)	Anxiety, OR (95%CI)	Loneliness, β (95%CI)	Sleep status, OR (95%CI)
Crude model				
Screen time, h	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	0.032(-0.091, 0.156)	1.069(1.027, 1.112)**
Adjusted model				
Screen time, h	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	0.107(-0.023, 0.237)	1.049(1.005, 1.095)*

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 4 Mediating effect of sleep status on the association between screen time and mental health status (depression, anxiety, and loneliness).

	Depression, OR (95%CI)				Anxiety, OR (95%CI)			
	X→Y	X+M→Y	Indirect Effect (95%CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95%CI)	Proportion of Mediation (%)
Screen Time, h	1.118 (1.072,1.166)** *	1.115 (1.066, 1.166)***	0.017 (0.016, 0.033) *	13.73%	1.079 (1.023, 0.138)**	1.067 (1.010, 1.128)*	0.016 (0.001, 0.031)*	19.68%
Sleep Status, bad vs. good		5.044 (3.746, 6.793)***				4.449 (2.781,7.117)** *		

*P < 0.05, **P < 0.01, ***P < 0.001.

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Figure 1. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety.

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Sleep Status

Total Effect: 0.1259(p<0.001)
Direce Effect: 0.1086(p<0.001)
Indirect Effect: 0.0173(p=0.031)

Screen time → Depression

(A)

Sleep Status

Total Effect: 0.0808(p=0.004)
Direce Effect: 0.0649(p=0.022)
Indirect Effect: 0.0159(p=0.038)

Screen time → Anxiety

(B)

145x109mm (300 x 300 DPI)

Supplementary material

Sample size estimation

The number of cross-sectional study samples in this study was calculated using the following public disclosure:

$$n = \frac{z_\alpha{}^2 * p * (1-p)}{\delta^2}$$

In the formula, the meaning and value of each parameter are as follows:

a) α is Type I Error, and α is taken as 0.05 in this study；

b) δ is the allowable error, and δ is taken as 0.3 in this study;

c) p represents the incidence rate, and the amount of depression was chosen as the variable of interest to estimate the sample size, with a pre-experimental result of depression incidence = 0.3.

After substituting each parameter into the calculation, n=897. Considering certain errors and experimental mistakes, Finally, 1200 questionnaires were distributed.

Table S1. Distribution of Screen Time and Sleep Status among Mental Health Status(Depression, Anxiety, Loneliness)

Characteristics	Depression			Anxiety			Loneliness	
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P		P
Screen time, h, mean (SD)	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	0.0334[a]	0.2755
Sleep status, mean (SD)	4.53 (2.37)	6.97 (2.79)	<0.001	5.13 (2.54)	8.08 (3.02)	<0.001	0.2146[a]	<0.001

a. Spearman's correlation coefficient

b. Screen Time, Sleep Status and Loneliness are continuous variables

c. Depression and Anxiety are binary variables

Table S2. Association of Screen time with Depression, Anxiety, Loneliness, and Sleep status

	Depression, OR (95% CI)	Anxiety, OR (95% CI)	Loneliness, β (95% CI)	Sleep status, β (95% CI)
Crude model				
Screen time	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	0.032(-0.091, 0.156)	0.153(0.101, 0.205)***
Adjusted model				
Screen time	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	0.107(-0.023, 0.237)	0.117(1.005, 1.095)***

a. *p<0.05, **p<0.01, ***p<0.001

Table S3. Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status(Depression, Anxiety, Loneliness)

	Depression, OR (95% CI)				Anxiety, OR (95% CI)			
	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)
Screen Time	1.118 (1.072,1.166)***	1.095 (1.045, 1.146)***	0.044 (0.022, 0.066) ***	32.89%	1.079 (1.023, 0.138)**	1.034 (0.973, 1.098)	0.046 (0.023, 0.068)***	57.48%
Sleep Status		1.457 (1.373, 1.547)***				1.477 (1.375, 1.587)***		

a. *p<0.05, **p<0.01, ***p<0.001

Table S4. Distribution of Screen Time and Sleep Status among Mental Health Status(Depression, Anxiety, Loneliness)

Characteristics	Depression			Anxiety			Loneliness		
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P	No(N=463)	Yes(N=607)	P
Screen time, h, mean (SD)	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	8.02 (3.21)	8.19 (3.25)	0.41
Sleep status, mean (SD)	4.53 (2.37)	6.97 (2.79)	<0.001	5.13 (2.54)	8.08 (3.02)	<0.001	4.96 (2.59)	6.08 (2.92)	<0.001

a. Screen Time and Sleep Status are continuous variables

b. Depression, Anxiety and Loneliness are binary variables

Table S5. Association of Screen time with Depression, Anxiety, Loneliness, and Sleep status

	Depression, OR (95% CI)	Anxiety, OR (95% CI)	Loneliness, OR (95% CI)	Sleep status, β (95% CI)
Crude model				
Screen time	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	1.016(0.978,1.055)	0.153(0.101, 0.205)***
Adjusted model				
Screen time	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	1.031(0.989, 1.075)	0.117(1.005, 1.095)***

a. *p<0.05, **p<0.01, ***p<0.001

Table S6. Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status(Depression, Anxiety, Loneliness)

	Depression, OR (95% CI)				Anxiety, OR (95% CI)			
	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)
Screen Time	1.118 (1.072,1.166)***	1.095 (1.045, 1.146)***	0.044 (0.022, 0.066) ***	32.89%	1.079 (1.023, 0.138)**	1.034 (0.973, 1.098)	0.046 (0.023, 0.068)***	57.48%
Sleep Status		1.457 (1.373, 1.547)***				1.477 (1.375, 1.587)***		

a. *p<0.05, **p<0.01, ***p<0.001

Table S7. Distribution of Screen Time and Sleep Status among Mental Health Status(Depression, Anxiety, Loneliness)

Characteristics	Depression			Anxiety			Loneliness		
	No(N=604)	Yes(N=466)	P	No(N=902)	Yes(N=168)	P	No(N=463)	Yes(N=607)	P
Screen time, h, mean (SD)	7.79 (3.14)	8.83 (3.31)	<0.001	7.98 (3.18)	8.85 (3.40)	0.001	8.02 (3.21)	8.19 (3.25)	0.41
Sleep status, n(%)									
Good(N=398)	349(47.4%)	49 (14.7%)	<0.001	375(41.6%)	23(13.7%)	<0.001	216(46.7%)	182(30.0%)	<0.001
Bad(N=672)	388(52.6%)	284 (85.3%)		527(58.4%)	145 (86.3%)		247(53.3%)	425(70.0%)	

a. Screen Time is continuous variable

b. Depression, Anxiety, Loneliness and Sleep Status are binary variables

Table S8. Association of Screen time with Depression, Anxiety, Loneliness, and Sleep status

	Depression, OR (95% CI)	Anxiety, OR (95% CI)	Loneliness, OR (95% CI)	Sleep status, OR (95% CI)
Crude model				
Screen time	1.107(1.065, 1.151)**	1.084(1.032, 1.139)***	1.016(0.978,1.055)	1.069(1.027, 1.112)**
Adjusted model				
Screen time	1.118(1.072,1.166)***	1.079(1.023, 1.138)**	1.031(0.989, 1.075)	1.049(1.005, 1.095)*

a. *p<0.05, **p<0.01, ***p<0.001

Table S9. Mediating Effect of Sleep Status on the Association Between Screen Time and Mental Health Status(Depression, Anxiety, Loneliness)

	Depression, OR (95% CI)				Anxiety, OR (95% CI)			
	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)	X→Y	X+M→Y	Indirect Effect (95% CI)	Proportion of Mediation (%)
Screen Time	1.118 (1.072,1.166)***	1.115 (1.066, 1.166)***	0.017 (0.016, 0.033) *	13.73%	1.079 (1.023, 0.138)**	1.067 (1.010, 1.128)*	0.016 (0.001, 0.031)*	19.68%
Sleep Status		5.044 (3.746, 6.793)***				4.449 (2.781,7.117)***		

a.   *p<0.05, **p<0.01, ***p<0.001

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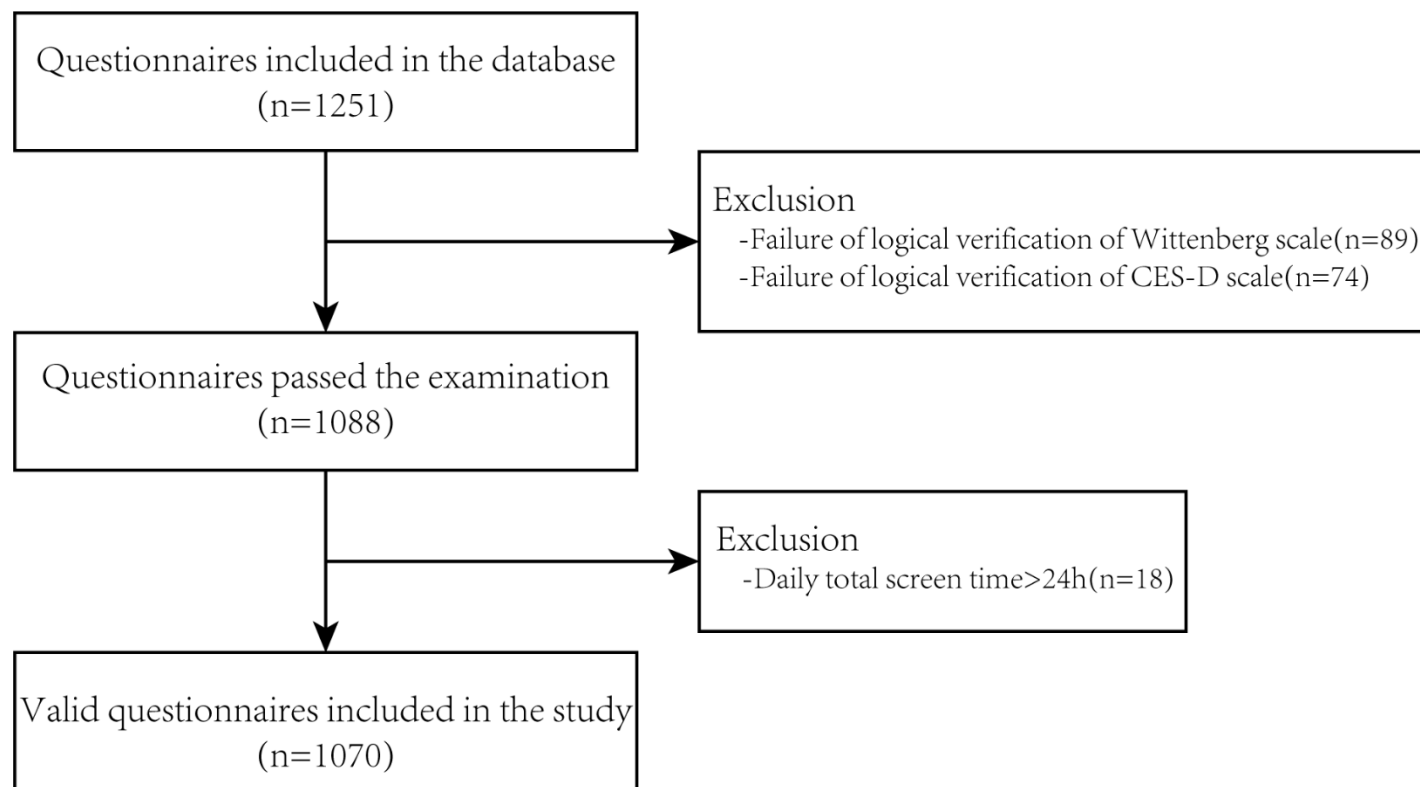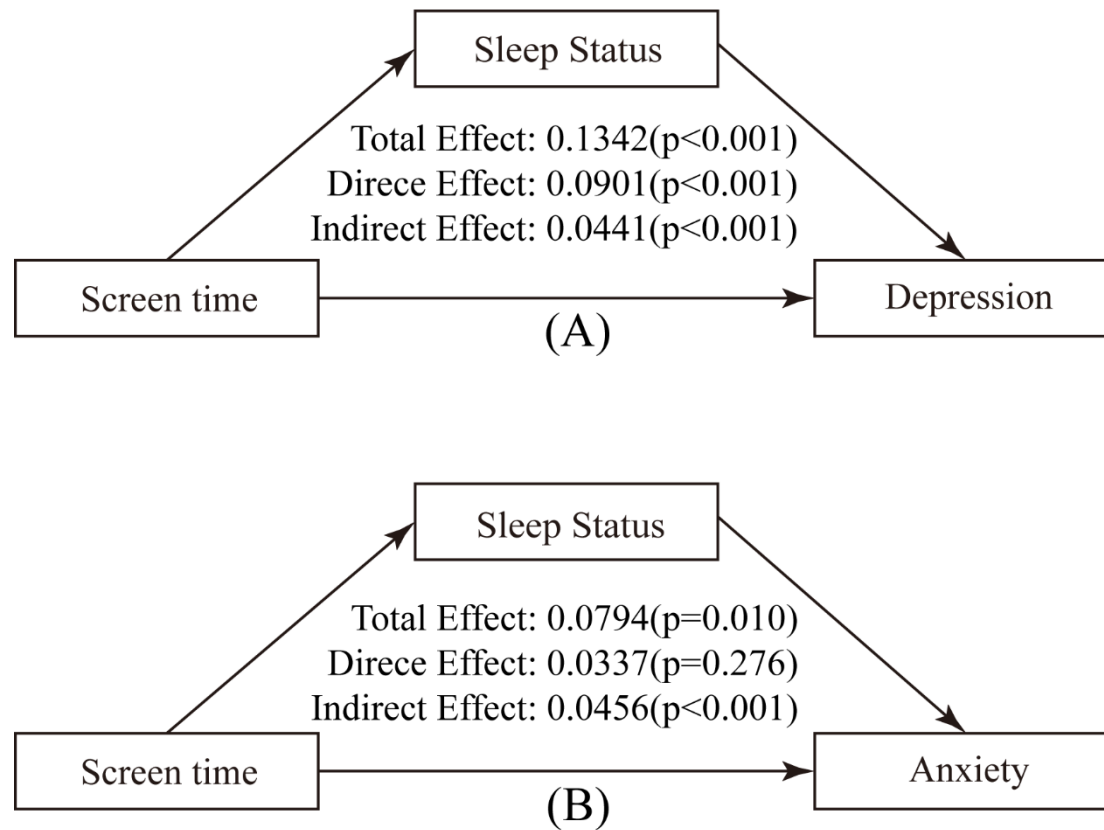28
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Figure S1. Flow chart of questionnaire screening.

Figure S2. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety. (Screen Time, Sleep Status and Loneliness are continuous variables, Depression and Anxiety are binary variables)

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Sleep Status

Total Effect: 0.1342(p<0.001)
Direce Effect: 0.0901(p<0.001)
Indirect Effect: 0.0441(p<0.001)

Screen time

Depression

(A)

Sleep Status

Total Effect: 0.0794(p=0.010)
Direce Effect: 0.0337(p=0.276)
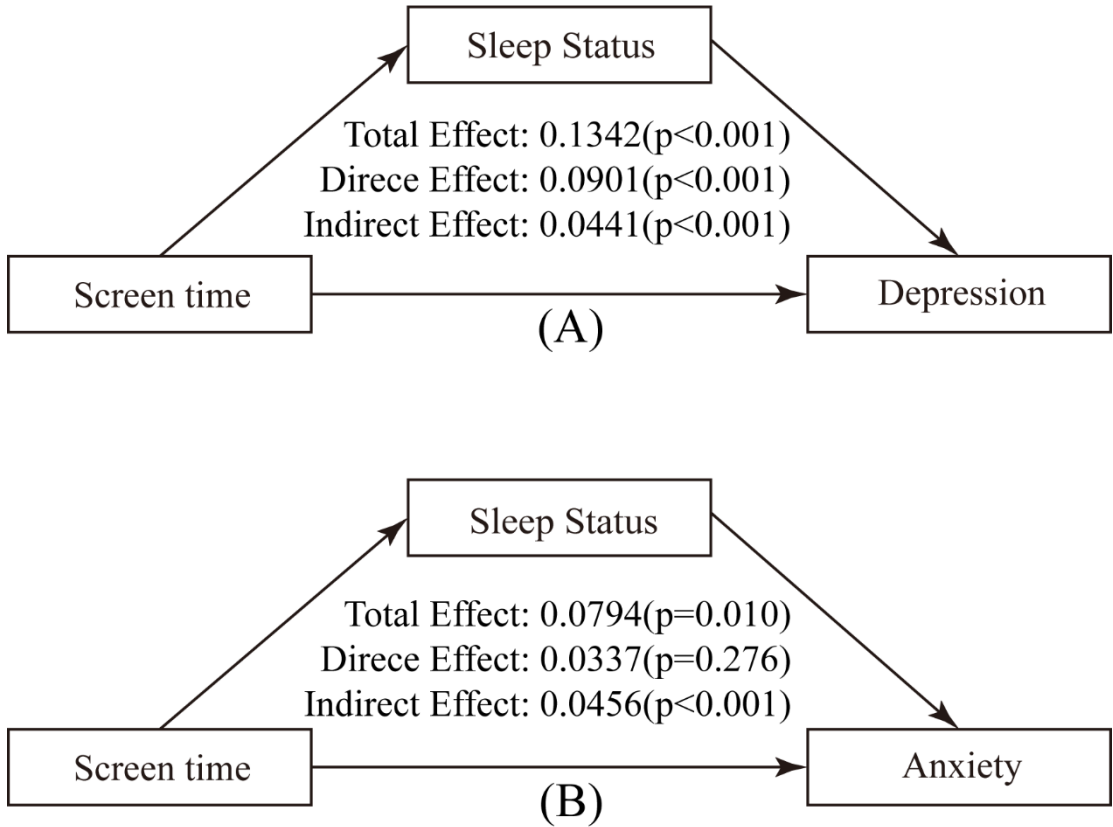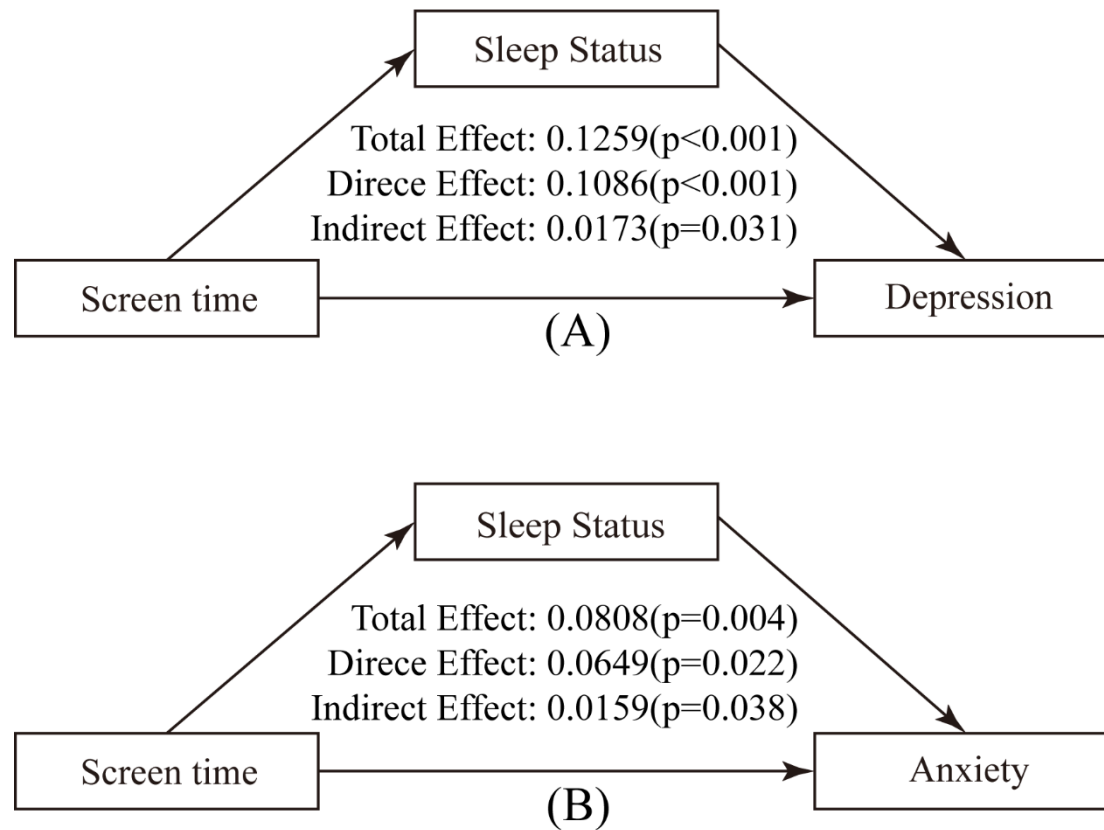Indirect Effect: 0.0456(p<0.001)

Screen time

Anxiety

(B)

Figure S3. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety. (Screen Time and Sleep Status are continuous variables, Depression, Anxiety and Loneliness are binary variables)

Figure S4. The intermediary model. (A) Screen time + sleep status → depression. (B) Screen time + sleep status → anxiety. (Screen Time is continuous variable, Depression, Anxiety, Loneliness and Sleep Status are binary variables)

STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5,6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5,6*
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6,7
		(*b*) Describe any methods used to examine subgroups and interactions	6,7
		(*c*) Explain how missing data were addressed	6,7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6,7
		(*e*) Describe any sensitivity analyses	8
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure S1
		(b) Give reasons for non-participation at each stage	Figure S1
		(c) Consider use of a flow diagram	Figure S1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	16
		(b) Indicate number of participants with missing data for each variable of interest	16
Outcome data	15*	Report numbers of outcome events or summary measures	17

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	18
		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	17
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8
Discussion			
Key results	18	Summarise key results with reference to study objectives	7,8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9,10
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.