Sleep Medicine 85 (2021) 246–258

Contents lists available at ScienceDirect

Sleep Medicine

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

Original Article

How does the COVID-19 affect mental health and sleep among Chinese adolescents: a longitudinal follow-up study

Yun Li [a, b, 1], Ying Zhou [a, c, 1], Taotao Ru [a, c, *, 1], Jiaxing Niu [b], Meiheng He [b], Guofu Zhou [a, c]

[a] *Lab of Light and Physio-psychological Health, National Center for International Research on Green Optoelectronics, South China Normal University, Guangzhou 510006, China*
[b] *School of Psychology, South China Normal University, Guangzhou 510631, China*
[c] *Guangdong Provincial Key Laboratory of Optical Information Materials and Technology & Institute of Electronic Paper Displays, South China Academy of Advanced Optoelectronics, South China Normal University, Guangzhou 510006, China*

ARTICLE INFO

Article history:
Received 5 April 2021
Received in revised form
22 June 2021
Accepted 2 July 2021
Available online 13 July 2021

Keywords:
COVID-19
Anxiety
Depression
Sleep disturbance
Chronotype

ABSTRACT

Objective: The Corona Virus Disease-19 (COVID-19) pandemic has evolved into the largest public health event in the world. Earlier COVID-19 studies have reported that the pandemic caused widespread impacts on mental health and sleep in the general population. However, it remains largely unknown how the prevalence of mental health problems and sleep disturbance developed and interacted in adolescents at different times in the epidemic.
Methods: 831 teenagers (aged 14–19) underwent a longitudinal follow-up study to evaluate the prevalence of mental health problems and sleep disturbance among adolescents before, during, and after the COVID-19 breakout in China and to explore the interaction between mental health and sleep across the three measurements. The chronotype, anxiety and depression level, sleep quality, and insomnia were investigated during each measurement.
Results: The adolescents had delayed sleep onset and sleep offset time, longer sleep duration during the quarantine than before and after the epidemic, whereas their chronotype tended to morning type during the epidemic. Yet, the highest prevalence of anxiety, depression, poor sleeper, and insomnia symptoms were observed before but not during the COVID-19 breakout. The females and adolescents who were eveningness type showed significantly higher anxiety and depression levels, poorer sleep quality, and severe insomnia status than the males and the intermediate and morning types. Sleep disturbance was positively associated with mental problems among three measurements. Pre-measured depression level significantly predicted sleep disturbance level at follow-ups.
Conclusion: These findings suggested that adolescents' high prevalence of mental health and sleep problems occurred before the COVID breakout and decreased during and after the epidemic. Gender and chronotype were significant risk factors associated with affective and sleep disturbances. Depression positively predicted later sleep problems, but not vice versa.

1. Introduction

The Corona Virus Disease-19 (COVID-19) pandemic was a global threat for its extremely high transmission rate and high infectivity [1], which has resulted in the death of nearly 2.80 million worldwide by March 31, 2021(WHO, 2021). Besides, the COVID-19 outbreak also brought unprecedented mental and sleep problems to the infected patients, healthcare workers, and the general public [2,3]. To effectively control and mitigate the spread of infection, the Chinese government first implemented social isolation policy on February 2, 2020, and forced people to remain homebound [4]. This home confinement has profoundly impacted individuals' daily routines and psychopathology. Of all the people affected, the adolescents were established to be particularly susceptible to COVID-19-related changes in sleep [5] and mental health [6–8]. Especially that home quarantines and national school closures made the teenagers stay at home and study online for nearly three months in China. Earlier COVID-19 studies reported that these isolation measures caused more sleep disturbances [9] and a higher prevalence of anxiety and depression in adolescents than older adults

* Corresponding author. Lab of Light and Physio-psychological Health, National Center for International Research on Green Optoelectronics, South China Normal University, Guangzhou 510006, China.
E-mail address: taotao.ru@m.scnu.edu.cn (T. Ru).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.sleep.2021.07.008
1389-9457/

[10]. Thus, to evaluate the COVID-19 breakout induced changes of physical and psychological health in adolescents should be a focal point of the epidemic research.

The lack of regular social interaction [11,12], decreased physical activity level [13,14], and more electronic screen time [15,16] were all considered as the contributors to poor sleep quality and mental disturbance, and when combined with such a major public health event-the COVID-19 outbreak, were expected to induce remarkable changes in sleep and psychological health in the short and long term [7,17–19]. In line with these predictions, several cross-sectional and qualitative studies from different countries revealed a high prevalence of anxiety and depression in confined adolescents [20–23]. A longitudinal study, in which 1339 adolescents aged between 9 and 18 from three countries (USA, Netherlands, Peru) were recruited, indicated that the symptoms of depression significantly increased during the pandemic, whereas the symptoms of anxiety remained unchanged [24]. Meanwhile, another longitudinal study (two-time points) with 248 adolescents (aged 13 to 16) showed that both the symptoms of depression and anxiety increased significantly during the lockdown compared to the non-epidemic period [25].

In addition to the changes in psychological health, the current COVID-19 studies reported either negative or positive effects of the COVID-19 quarantine on sleep indicators in adolescents. For instance, the cross-sectional studies established that home confinement resulted in poor sleep quality [26], severe insomnia symptoms [27], and delayed chronotype [28]. Similarly, the findings from prospective studies also demonstrated that adolescents' bedtimes and wake times tended to be later [29], and chronotype shifted towards the evening type during the COVID-19 pandemic [30]. Nevertheless, the findings even revealed improvements in sleep during the COVID-19 pandemic [30–32]. For instance, one study by Genta, Rodrigues Neto [30] reported that those who had short sleep duration before the outbreak had increased sleep duration and improved sleep quality during the lockdown. Furthermore, a qualitative study of 45 adolescents also reported higher sleep quality, longer sleep duration, and less daytime sleepiness during COVID-19 compared to before COVID-19 [31]. These COVID-19 induced benefits of sleep could be partly explained by the fact that people had more flexible sleep time and active–rest routine during home quarantine.

The cross-sectional COVID-19 studies have also demonstrated the relationship between the change of mental health and sleep due to the COVID-19 pandemic [21,26,33–36]. For instance, Hyun, Hahm [33] reported that the symptoms of depression and anxiety explained poor sleep quality in young adults during the COVID-19 pandemic. Navarro-Soria and Real-Fernández [36] demonstrated that children and adolescents under home confinement had higher state anxiety than the non-confinement ones, and state anxiety could further impact sleep. Recently, a larger-scale study with 6882 participants (18–94 years) from 59 countries reported that poorer sleep health was highly associated with more severe depression and anxiety symptoms during the COVID-19 pandemic [35]. These findings suggested that the COVID-19 pandemic-induced disturbance of sleep and mental health might interact. Findings from the longitudinal studies conducted during the non-epidemic pandemic had even revealed - although not always-the causality between sleep disturbance and mental health [37–42]. Several longitudinal studies reported that sleep disturbance acted as a precursor to anxiety and depressive disorder, but no predictive role of affective disorders was revealed in developing sleep disturbance [39,41,42]. At the same time, other studies reported the predictive role of anxiety and depression on sleep outcomes in adolescents at follow-ups, but not vice versa [38,40].

To date, several longitudinal studies investigated the changes in mental health [24,43–48] or sleep [49] during the outbreak separately. Yet, only a few reported about the longitudinal changes of mental health and sleep during the lockdown period in one study [30,50], and still leave their interactions unexplored. Besides, most of these longitudinal studies were conducted in the adult group [24,44,45] or the general population [46,48,51], less attention has been paid to the adolescents group. Also, these longitudinal studies included two waves: before and during the epidemic outbreak [24,30,44–46,50], leading less powerful to track how mental health and sleep outcomes developed and interacted in adolescents over time in the COVID-19 pandemic.

Hence, we conducted a longitudinal follow-up study to evaluate the development of mental health problems and sleep disturbance in adolescents before, during, and after the COVID-19 breakout in China and explore the interaction effects between mental health and sleep outcomes across three measurements. Previous findings revealed that the individual characteristics (ie, Gender and Chronotype) played a moderator role in the impacts of the COVID-19 pandemic on mental health and sleep. For instance, the female experienced higher anxiety/depression levels [50,52] and more severe sleep disturbance [17,53] than males during the pandemic. In addition, individuals who were evening type could be more seriously affected by epidemic isolation, showing higher levels of anxiety and depression symptoms and more sleep problems [27,54–56]. Thus, the potential group difference between gender and chronotype in sleep and mental health would also be investigated in the current study.

2. Method

2.1. Design and participants

The current study was conducted using an online survey through the Wenjuanxing platform [57]. 1020 teenage students aged between 14 and 19 ($M_{age} = 15.87 \pm 0.74$, 601 girls) from three public commuter secondary vocational schools in Southern China (the third-worst affected province) were recruited to participate in a longitudinal study project aiming to address changes in the mental health and sleep status. Thus, all the participants completed their first measure on December 9, 2019 (before the COVID-19 outbreak, wave 1). After the outbreak, we conducted the second and third measurements at the previously scheduled time, March 19, 2020 (during the lockdown, wave 2) and June 18, 2020 (post to the COVID-19 outbreak, wave 3).

The national epidemic trend of COVID-19 in China from January 10 to June 20, 2020, was shown in Fig. 1, with a peak ($n = 58{,}016$) in the number of existing confirmed cases on February 17, 2020 (see Fig. 1). All participants were non-diseased, and none of them had self-reported complaints on physical and mental health. Finally, data from 831 participants (aged 14–19, Mage = 15.89 ± 0.74, 503 girls) were taken into further analysis after removing the data from those who did not complete all three online surveys. In order to check whether the loss of subjects affects the estimation of the longitudinal relationship between variables, we compared the gender (treated as dummy variables), age, scores of chronotype, sleep quality, insomnia, anxiety, and depression between the subjects who participated in the whole measurement and those who participated in the first measurement by independent sample t-test. The results showed no significant difference in all variables surveyed (all $p > 0.05$).

2.2. Measurements

2.2.1. Demographics

Participants' demographics, including gender, age, and annual household income, were self-reported when they participated in the first online survey. Remarkably, additional questions on

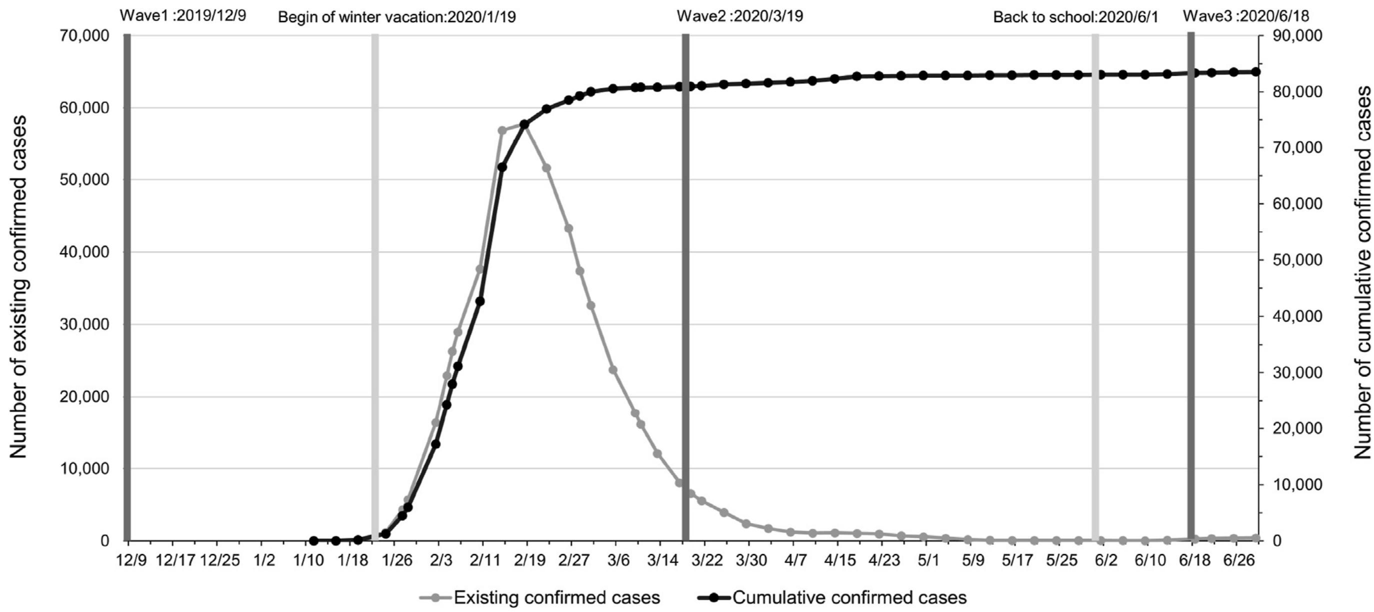

Fig. 1. The national pandemic trend of the 2019 coronavirus disease (COVID-19) in China from January 10 h to June 26, 2020; existing confirmed cases = cumulative confirmed cases − cured cases − death cases.

whether they and their close family or friends were affected were added in the second and third measurements.

2.2.2. Chronotype

The reduced version of the Morningness–Eveningness Questionnaire (rMEQ) was used to assess chronotype preference, which has been found to have adequate psychometric properties in the Chinese population [58,59]. The total score of rMEQ ranged from 4 to 25, with the following cut-offs: 4–11 (evening-type); 12–17 (intermediate-type); 18–25(morning-type). The McDonald's Omega's values of rMEQ in the current study were 0.52, 0.48, and 0.65 in wave 1, wave 2, and wave 3, respectively.

2.2.3. Mental health

2.2.3.1. Anxiety. The Zung Self-Rating Anxiety Scale (SAS) of 20-item [60] was used to evaluate various symptoms of anxiety in the past week, in which participants responded on a 4-point Likert scale (1 = never, 4 = most of the time) and the total score of SAS > 50 is considered to have anxiety symptom (51–59, mild anxiety; 60–69, moderate anxiety; ≥70, severe anxiety). The McDonald's Omega's values of SAS in the current study were 0.85, 0.90, and 0.94 in wave 1, wave 2, and wave 3, respectively.

2.2.3.2. Depression. The depressive symptom was assessed with the Beck Depression Inventory (BDI-II) [61], which comprised 21-item assessing the severity of depression in the past two weeks. All responses were made on a 4-point Likert scale, and the total score >13 was considered to experience depression (14–19, mild depression; 20–28, moderate depression; 29–63, severe depression). The McDonald's Omega's values of BDI-II in the current study were 0.94, 0.95, and 0.96 in wave 1, wave 2, and wave 3, respectively.

2.2.4. Sleep status

2.2.4.1. Sleep quality. Subjective sleep quality was measured with the Pittsburgh Sleep Quality Index (PSQI) [62]; it consists of 18 self-report questions assessing the general sleep quality/impairment during the past month. These 18 items are grouped into seven subscales (subjective sleep quality, sleep latency, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction). Scores higher than 5 indicate poor sleep. The McDonald's Omega's values of PSQI in our study were 0.77, 0.84, and 0.87 in wave 1, wave 2, and wave 3, respectively.

2.2.4.2. Insomnia symptoms. The insomnia symptoms were assessed with the Insomnia Severity Index of 7-item (ISI) [63], in which participants responded on a 7-point Likert scale (0 = not at all, 4 = very severe) and refer to the previous two weeks. “No clinically significant insomnia” was identified if the final score was between 0 and 7, “Mild insomnia” if it was between 8 and 14, “Clinical insomnia (moderate severity)” if it ranged from 10 to 21, and “Clinical insomnia (severe)” if it was between 22 and 28. The McDonald's Omega's values of ISI in the current study were 0.86, 0.89, and 0.89 in wave 1, wave 2, and wave 3, respectively.

2.3. Procedure

Participants were informed to participate in a longitudinal follow-up study and required to complete an online survey five times with an interval of about three months. In the current study, we would like to present the date from the first three surveys that were conducted on December 9, 2019 (before the COVID-19 outbreak, wave 1), March 19, 2020 (during the lockdown, wave 2), and June 18, 2020 (post to the COVID-19 outbreak, wave 3), respectively. A set of self-rating questionnaires including rMEQ, SAS, BDI, PSQI, and ISI were employed during each survey. Participants' demographics were collected during the first survey. The questionnaire was only available from 9 a.m. to 24:00 p.m. on the measurement day during each data collection. Students were in school when they participated in the first and third online survey and were in home quarantine when they completed the second survey online. It is worth mentioning that for all the participants in the current study, the final exam for the fall semester of the 2019–2020 academic year was held from January 12 to 18, 2019, and the winter vacation started on January 19, 2019. For the spring semester of the 2019–2020 academic year, the online course started on February 10, 2020, and the investigated students returned to school on June 1, 2020, and the semester ended on July 12, 2020. The study protocol was submitted and approved by the Ethics Reviews Committee on Research involving Humans at the local university. All the subjects and their parents signed an informed consent form before the first survey.

2.4. Statistical analysis

First, the omega reliability coefficients of all scales were calculated to verify the reliability and validity of all the questionnaires employed in the current study by the OMEGA macro [64] with SPSS 26.0 (IBM, USA). Besides, considering that each individual underwent three repeated measurements (the measurements nested within participant ID), the Linear Mixed Model was used to separate the effects between individuals and within individuals with R Studio 4.0.3 ('psych' and 'plyr' packages were used for the preparatory analyses, 'emmeans,' 'Sjstats,' 'lme4' and 'lmerTest' packages were used for the statistical analysis) [65]. We first compared the differences of sleep latency, sleep onset and offset time, sleep duration, and chronotype across three measurements. In these LMM analyses, Participant (P) was added as a random intercept, and Wave (1/2/3) was added as a fixed factor; the model was specified as follows: $Y_{ijk} = \beta 0 + P00k + \beta 1 \cdot Wave + e_{ijk}$. Then, the impact of time points (wave 1, wave 2, wave 3), gender, and chronotype in baseline (Wave1) on depression, anxiety, sleep quality, and insomnia were analyzed. In these LMM analyses, Participant (P) was added as a random intercept, Gender (Male/Female), Wave (1/2/3) and Chronotype (Evening-type/Intermediate/Morning-type) in baseline, the two-way interactions of Wave*Gender and Wave*Chronotype were added as fixed factors. The model was specified as follows: $Y_{ijk} = \beta 0 + P00k + \beta 1 \cdot Wave + \beta 2 \cdot Gender + \beta 3 \cdot Chronotype + \beta 4 \cdot Wave*Gender + \beta 5 \cdot Wave*Chronotype + e_{ijk}$. The dependent variables were anxiety, depression, sleep quality, and insomnia scores. A separate LMM analysis was conducted for each dependent variable.

In addition, Pearson correlation analyses were conducted with R Studio ('Hmisc' packages) to examine the associations between mental health and sleep status across the three waves. Then, we calculated intra-class correlations (ICC) for anxiety, depression, insomnia symptoms sleep quality. ICC can be defined as the proportion of the variance explained by differences between subjects. Later, a Random-Intercept Cross-Lagged Panel Model (RI-CLPM) was used to examine the between-subject and within-subject relations between psychological health and sleep status in a comprehensive model by Mplus version 7.4 [66]. In each RI-CLPM model, the common components of mental health and sleep outcomes in repeated three waves were extracted to form a latent variable (Random intercept, R), which was used to represent the average level of repeated measurement variables across three waves (ie, the "trait" component). After extracting the random intercept, the remaining part (C) of each repeated measurement variable reflected the fluctuations around the average level at each specific time point (ie, the "contextual" component). Simultaneously, gender was controlled in all RI-CLPM models to exclude its influences.

3. Results

3.1. Common method deviation test

Harman single factor test [67] was conducted to test whether the influence of common method deviation was obtained in the current study. Results showed a total of 15, 13, and 10 factors with eigenvalues greater than one in wave 1, wave 2, and wave 3, respectively. All the explanatory rates of the first common factor (25.8% in wave 1, 29.9% in wave 1, and 18.2% in wave 1) were below 40%, indicating no common method deviation existed in the three measurements.

3.2. Change of sleep and chronotype across the three measurements

The descriptive statistics of sleep outcomes and chronotype were presented in Table 2. LMM analysis revealed that the COVID-19 epidemic yielded significant changes in chronotype and sleep outcomes, including bedtime, sleep latency, wake-up time, and sleep duration (see Table 1). Specifically, the adolescents went to bed later and woke up later significantly during the quarantine than before and after the COVID-19 outbreak (see Fig. 2A and C), and their sleep duration during the quarantine was significantly longer than that before and after the outbreak (see Fig. 2D). In addition, the sleep latency was significantly shorter after the epidemic than before and during the epidemic, while the sleep latency did not differ significantly between the first and second measurements (see Fig. 2B). The adolescents' rMEQ score was significantly higher in wave 3 than those in wave 1 and wave 2, indicating that adolescents' chronotype shifted to morningness after the COVID-19 outbreak. No significant difference was found between wave 1 and wave 2 (see Fig. 2E).

3.3. Prevalence of anxiety, depression, insomnia, poor sleeper, and extreme chronotype

During the three measurement waves, the prevalence of anxiety symptoms (mild to severe) was 27.7%, 23%, 25.8%, respectively. The prevalence of depression (35.4%, 27.8%, 23.2%), poor sleeper (76.4%, 55%, 49.7%) and insomnia symptoms (21.7%, 21.1%, 14.8%) tended to decrease across three waves. Besides, compared to the prevalence in Wave 1, the number of participants of evening-type in Wave 2 and Wave 3 decreased, while the number of participants of morning-type in Wave 2 and Wave 3 increased. Notably, there were significant differences in the prevalence of depression, insomnia symptoms, poor sleeper, and chronotype across three waves (all $p < 0.001$) (see Table 2).

3.4. Impact of wave, gender, and chronotype in baseline on mental health and sleep status

For the anxiety level, the Wave yielded a significant main effect [F (2,1690) = 3.410, p = 0.03, η_p^2 = 0.004], with the anxiety level higher in Wave 3 (EMM ± SE = 46.50 ± 0.48) than Wave 2 (EMM ± SE = 45.20 ± 0.43, p = 0.04), no other significant differences were found between the Waves. Besides, the main effect of Chronotype was significant [F (2, 2120) = 6.96, p = 0.001, η_p^2 = 0.008], evening-type adolescents' had significantly higher anxiety scores (EMM ± SE = 47.40 ± 0.61) than adolescents of intermediate type (EMM ± SE = 45.60 ± 0.34, p = 0.006) and morning-type (EMM ± SE = 44.80 ± 0.45, $p < 0.001$); but anxiety level did not differ between the intermediate and morning-type. The interaction effect between Wave and Chronotype was not significant (p = 0.29) (see Table 3 and Fig. 3). The main effect of Gender did not reach significant (p = 0.19), but the interaction effect between Gender and Wave was significant [F(2,1577) = 18.86, $p < 0.001$, η_p^2 = 0.02]. The post-hoc analysis revealed girls (EMM ± SE = 47.50 ± 0.51) experienced higher anxiety level than boys in Wave 1 (EMM ± SE = 44.70 ± 0.59, p = 0.001), while anxiety level did not differ between girls and boys in Wave2 (p = 0.25) and in Wave 3 (p = 0.08) (see Table 3 and Fig. 3).

For depression level, the main effect of Wave was significant [F(2,1668) = 22.93, $p < 0.001$, η_p^2 = 0.03], with the higher depression score in Wave 1 (EMM ± SE = 11.14 ± 0.44) than that in Wave2 (EMM ± SE = 9.32 ± 0.45, $p < 0.001$) and Wave3 (EMM ± SE = 7.85 ± 0.50, $p < 0.001$). The main effect of Chronotype was significant [F (2,2061) = 39.11, $p < 0.001$, η_p^2 = 0.04), with the higher depression score in adolescents of evening-type

Table 1
The result of variance analysis of bedtime, sleep latency, wake-up time, sleep duration, and rMEQ at wave 1, wave 2, and wave 3 (N = 831).

		Mean	SE.	Wave	*p*
Bedtime	Wave 1	22:57:52	0:02:05	F (2,1659) = 43.26	<0.001
	Wave 2	23:22:13	0:03:02		
	Wave 3	22:59:43	0:02:23		
Sleep latency (min)	Wave 1	14.74	0.56	F (2, 1644) = 21.38	<0.001
	Wave 2	14.33	0.65		
	Wave 3	10.87	0.44		
Wake-up time	Wave 1	06:45:26	0:01:54	F (2,1657) = 275.68	<0.001
	Wave 2	08:05:48	0:03:08		
	Wave 3	06:57:54	0:03:07		
Sleep duration (hour)	Wave 1	6.73	0.05	F (2,1651) = 28.84	<0.001
	Wave 2	7.18	0.06		
	Wave 3	6.70	0.06		
rMEQ	Wave 1	14.55	0.11	F (2,1598) = 181.53	<0.001
	Wave 2	14.61	0.12		
	Wave 3	16.64	0.12		

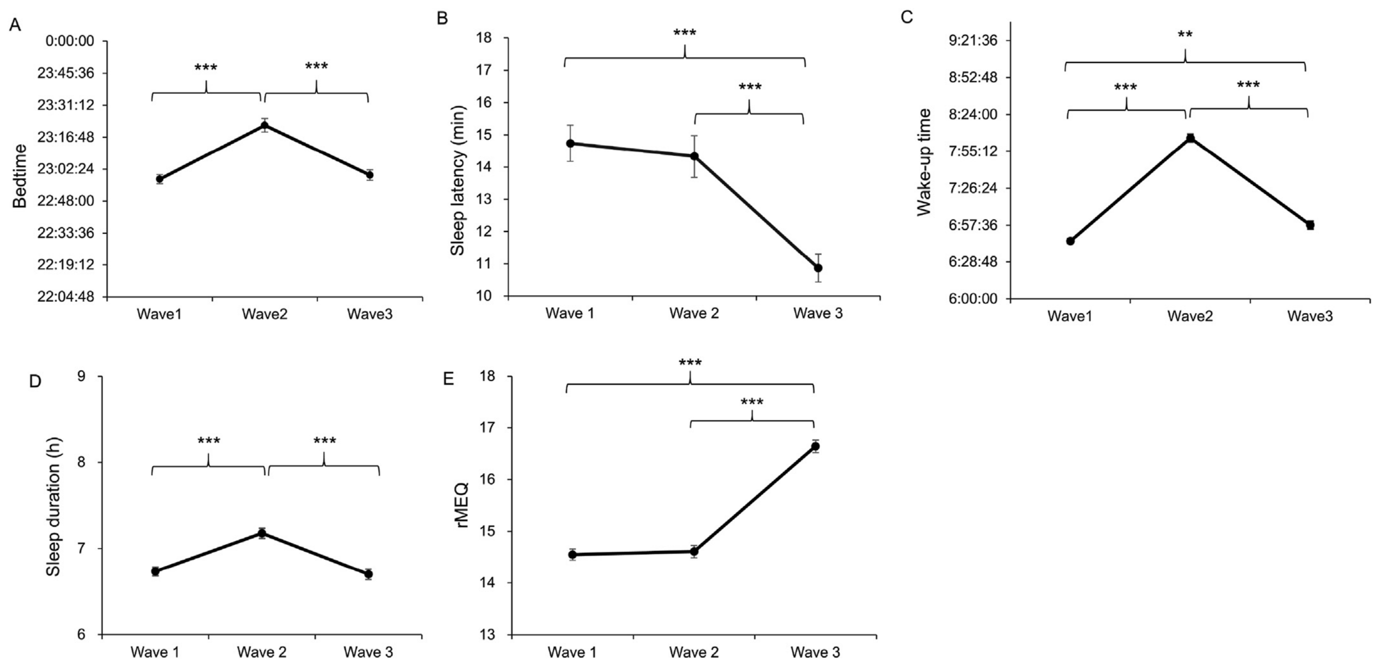

Fig. 2. A–E: The mean and standard errors of bedtime, sleep latency, wake-up time, sleep duration, and rMEQ across three measurements. Note. ** means $p < 0.01$; *** means $p < 0.001$.

(EMM ± SE = 12.02 ± 0.64) than those of intermediate (EMM ± SE = 9.85 ± 0.36, $p = 0.001$) and morning-type (EMM ± SE = 6.43 ± 0.48, $p < 0.001$). The depression score of the intermediate adolescents was also significantly higher than that of the morning-type individuals ($p < 0.001$). The interaction effect between Wave and Chronotype was not significant ($p = 0.08$) (see Table 3 and Fig. 3). The main effect of Gender was significant too [$F(1,824) = 15.58$, $p < 0.001$, $\eta_p^2 = 0.009$), the depression score of girls (EMM ± SE = 10.76 ± 0.45) was significantly greater than that of boys (EMM ± SE = 8.11 ± 0.55, $p < 0.001$). The interaction effect between Gender and Wave was significant [$F(2,1567) = 6.66$, $p = 0.001$, $\eta_p^2 = 0.007$]. The post-hoc analysis revealed girls reported higher depression scores than boys in Wave1 (13.02 ± 0.54 vs. 9.25 ± 0.63, $p < 0.001$) and Wave2 (10.77 ± 0.55 vs. 7.87 ± 0.66, $p < 0.001$), and there was no significant difference between gender in Waves 3 ($p = 0.09$) (see Table 3 and Fig. 3).

For sleep quality, the main effect of Wave was significant [$F(2,1777) = 29.79$, $p < 0.001$, $\eta_p^2 = 0.03$], with significantly worse sleep quality in Wave1(EMM ± SE = 6.99 ± 0.09) than those in Wave2 (EMM ± SE = 6.19 ± 0.09, $p < 0.001$) and Wave3 (EMM ± SE = 6.28 ± 0.11, $p < 0.001$), but sleep quality did not differ between Wave2 and Wave3. The main effect of Chronotype was significant [$F(2, 2348) = 37.31$, $p < 0.001$, $\eta_p^2 = 0.04$)], the evening-type adolescents (EMM ± SE = 7.22 ± 0.14) had worse sleep quality than those of intermediate type (EMM ± SE = 6.42 ± 0.07, $p < 0.001$) and morning type (EMM ± SE = 5.82 ± 0.10, $p < 0.001$), the sleep quality of the intermediate adolescents was also significantly poorer than those of morning type ($p < 0.001$). Additionally, the main effect of Gender was significant [$F(1,831) = 36.85$, $p < 0.001$, $\eta_p^2 = 0.02$], with poorer sleep quality for girls (EMM ± SE = 6.84 ± 0.08) than boys (EMM ± SE = 6.13 ± 0.10, $p < 0.001$). The interaction effect between Gender and Wave was not significant ($p = 0.93$), nor the interaction effect between Wave and Chronotype ($p = 0.98$) (see Table 3 and Fig. 3).

For the insomnia symptoms, the main effect of Wave was significant [$F(2, 1679) = 13.19$, $p < 0.001$, $\eta_p^2 = 0.02$], the adolescents'

Table 2
The prevalence of anxiety, depression, insomnia, poor sleeper, and chronotype at wave 1, wave 2, and wave 3 (N = 831).

Variables	Level	W1 n (%)	W2 n (%)	W3 n (%)	Chi 2	*p*
Anxiety	No	601 (72.32)	640 (77.02)	617 (74.25)		
	Mild	144 (17.33)	118 (14.20)	143 (17.21)		
	Moderate	58 (6.98)	48 (5.78)	44 (5.29)		
	Severe	28 (3.37)	25 (3.01)	27 (3.25)		
	Prevalence	230 (27.68)	191 (22.98)	214 (25.75)	4.87	0.09
Depression	No	537 (64.62)	600 (72.20)	638 (76.77)		
	Mild	108 (13.00)	76 (9.15)	56 (6.70)		
	Moderate	97 (11.67)	90 (10.83)	87 (10.50)		
	Severe	89 (10.71)	65 (7.82)	50 (6.02)		
	Prevalence	294 (35.38)	231 (27.80)	193 (23.23)	30.54***	<0.001
Insomnia	No	651 (78.3)	655 (78.8)	708 (85.2)		
	Mild	150 (18.05)	145 (17.45)	104 (12.52)		
	Moderate	27 (3.25)	27 (3.25)	11 (1.32)		
	Severe	3 (0.36)	4 (0.48)	8 (0.96)		
	Prevalence	180 (21.66)	176 (21.18)	123 (14.80)	15.70***	<0.001
Poor sleeper	No	192 (23.10)	369 (44.40)	413 (49.70)		
	Yes	635 (76.41)	457 (54.99)	413 (49.70)		
	NA	4 (0.48)	5 (0.60)	5 (0.60)		
	Prevalence	635 (76.41)	457 (54.99)	413 (49.70)	139.00***	<0.001
Chronotype	Evening-type	125 (15.16)	108 (13.00)	52 (6.26)		
	Intermediate	551 (66.31)	512 (61.61)	452 (54.39)		
	Morning-type	145 (17.45)	137 (16.49)	327 (39.35)	148.05***	<0.001
	NA	9 (1.08)	74 (8.90)	–		

Note. *** means $p < 0.001$.

Table 3
Descriptive statistics of mental health and sleep status in adolescents at wave 1, wave 2 wave 2, and wave 3 (EMM ± SE).

	Gender		Chronotype		
	Male (N = 503)	Female (N = 328)	Evening (N = 126)	Intermediate (N = 551)	Morning (N = 145)
W1 Anxiety	44.70 ± 0.59	47.50 ± 0.50	47.70 ± 0.75	47.1 ± 0.80	47.40 ± 1.13
W2 Anxiety	44.80 ± 0.62	45.70 ± 0.52	46.10 ± 0.41	44.7 ± 0.42	45.90 ± 0.45
W3 Anxiety	47.10 ± 0.66	45.8 ± 0.54	44.50 ± 0.70	43.90 ± 0.71	46.10 ± 0.50
W1 Depression	9.25 ± 0.63	13.02 ± 0.54	13.40 ± 0.77	11.93 ± 0.44	8.07 ± 0.72
W2 Depression	7.87 ± 0.66	10.77 ± 0.55	13.12 ± 0.83	9.14 ± 0.45	5.71 ± 0.73
W3 Depression	7.20 ± 0.70	8.49 ± 0.57	9.55 ± 1.16	8.48 ± 0.47	5.51 ± 0.52
W1 Sleep quality	6.62 ± 0.13	7.36 ± 0.11	7.66 ± 0.18	6.96 ± 0.09	6.35 ± 0.17
W2 Sleep quality	5.85 ± 0.14	6.53 ± 0.11	6.94 ± 0.19	6.09 ± 0.09	5.53 ± 0.17
W3 Sleep quality	5.92 ± 0.15	6.64 ± 0.12	7.07 ± 0.28	6.2 ± 0.10	5.58 ± 0.11
W1 Insomnia	4.39 ± 0.24	5.49 ± 0.20	6.23 ± 0.30	5.05 ± 0.17	3.54 ± 0.28
W2 Insomnia	3.83 ± 0.25	4.70 ± 0.21	5.85 ± 0.32	4.34 ± 0.17	2.60 ± 0.28
W3 Insomnia	3.67 ± 0.27	4.38 ± 0.22	5.49 ± 0.45	3.99 ± 0.18	2.60 ± 0.20

Note. The chronotype refers to the baseline chronotype (wave 1); W1 means wave 1, W2 means wave 2, W3 means wave 3.

insomnia score in Wave1(EMM ± SE = 4.94 ± 0.17) was significantly higher than that of Wave2 (EMM ± SE = 4.26 ± 0.17, $p < 0.001$) and Wave3 (EMM ± SE = 4.03 ± 0.19, $p < 0.001$), and there was no significant difference between Wave2 and Wave3 ($p = 0.71$). Additionally, the main effect of Chronotype was also significant [F (2,2097) = 64.32, $p < 0.001$, $\eta_p^2 = 0.07$]. The insomnia score of the evening-type adolescents (EMM ± SE = 5.86 ± 0.25) was significantly higher than that of intermediate type (EMM ± SE = 4.46 ± 0.14, $p = 0.001$) and morning type (EMM ± SE = 2.91 ± 0.18, $p < 0.001$), the score of intermediate adolescents was also significantly higher than that of the morning-type adolescents ($p < 0.001$). Besides, the main effect of Gender reached significant [$F(1,826) = 12.48$, $p < 0.001$, $\eta_p^2 = 0.007$], girls (EMM ± SE = 4.86 ± 0.17) showed higher insomnia scores than boys (EMM ± SE = 3.97 ± 0.21, $p < 0.001$). However, the interaction effects of Gender and Wave ($p = 0.37$), Chronotype and Wave ($p = 0.78$) were not significant (see Table 3 and Fig. 3).

3.5. Correlational analysis of psychology health and sleep status

The overview of correlations among mental health and sleep outcomes across three Waves was presented in Table 4. The correlational analysis revealed that anxiety, depression, sleep quality, and insomnia were significantly positively associated with each other in three waves.

3.6. Cross-lagged regression analysis of mental health and sleep

For anxiety, depression, insomnia symptoms, and sleep quality, the intra-class correlations (ICC) were 0.58, 0.62, 0.60, and 0.38, respectively. Thus, it indicated that differences between adolescents respectively explained 58%, 62%, 60%, and 38% of the variances in these four variables in the three measurement waves, and fluctuations respectively explained the remaining 42%, 38%, 40%, 62% within persons. The associations between adolescent mental health and sleep, divided into within- and between-person effects, are shown in Figs. 4–7.

The models for relationship between anxiety and sleep quality (model 1, see Fig. 4), anxiety and insomnia (model 2, see Fig. 5) fitted well (model 1, $\chi^2/df = 7.84$, CFI = 0.99, TLI = 0.93, RMSEA = 0.09, SRMR = 0.02; model 2, $\chi^2/df = 6.24$, CFI = 0.99, TLI = 0.97, RMSEA = 0.08, SRMR = 0.02). The modeling results revealed that anxiety level was moderately correlated with sleep quality ($r = 0.67$, $p < 0.001$) and insomnia ($r = 0.73$, $p < 0.001$) at the between-person

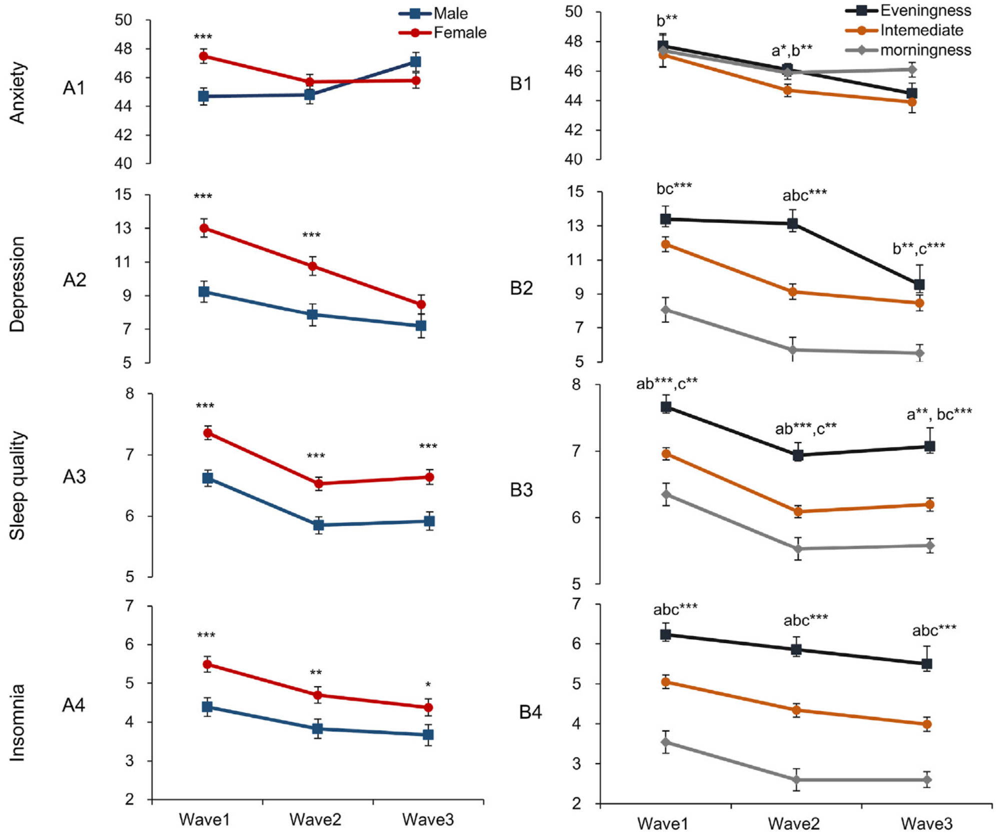

Fig. 3. A1-A4: The marginal mean and standard error scores of anxiety, depression, sleep quality, and insomnia for males and females across three measurements. B1–B4: The marginal mean and standard error scores of the anxiety, depression, sleep quality, insomnia for evening chronotype, intermediate chronotype, and morning chronotype across three measurements. Note. In B1–B4, a represents the difference between evening type and intermediate type, b represents the difference between evening type and morning type, and c represents the difference between intermediate type and morning type. * means $p < 0.05$; ** means $p < 0.01$; *** means $p < 0.001$.

Table 4
Correlation between all variables at wave 1, wave 2, and wave 3 (N = 831).

	1	2	3	4	5	6	7	8	9	10	11	12
1 gender	–											
2 SAS_W1	0.15***	–										
3 BDI_W1	0.17***	0.64***	–									
4 PSQI_W1	0.19***	0.43***	0.48***	–								
5 ISI_W1	0.14***	0.58***	0.62***	0.52***	–							
6 SAS_W2	0.05	0.63***	0.50***	0.30***	0.45***	–						
7 BDI_W2	0.14***	0.59***	0.73***	0.40***	0.53***	0.63***	–					
8 PSQI_W2	0.18***	0.39***	0.45***	0.43***	0.43***	0.42***	0.49***	–				
9 ISI_W2	0.13***	0.47***	0.52***	0.41***	0.65***	0.51***	0.61***	0.59***	–			
10 SAS_W3	−0.06	0.55***	0.42***	0.27***	0.37***	0.57***	0.42***	0.30***	0.36***	–		
11 BDI_W3	0.07*	0.48***	0.57***	0.31***	0.41***	0.48***	0.64***	0.37***	0.45***	0.53***	–	
12 PSQI_W3	0.18***	0.36***	0.38***	0.40***	0.41***	0.32***	0.39***	0.44***	0.44***	0.36***	0.49***	–
13 ISI_W3	0.11***	0.46***	0.50***	0.37***	0.58***	0.45***	0.52***	0.44***	0.64***	0.49***	0.66***	0.61***

Note. W1 means wave 1, W2 means wave 2, W3 means wave 3. The *p*-value in this table has been adjusted by the Benjamini–Hochberg method. * means $p < 0.05$, *** means $p < 0.001$.

level, suggesting that adolescents with higher anxiety levels tended to have poorer sleep quality and severer insomnia than those with lower anxiety levels. At the within-person level, after controlling the subjects' stability by estimating the random intercept, results showed the anxiety level in Wave 1 could predict that in Wave 2 (model 1: $\beta = 0.20$, $p = 0.005$; model 2: $\beta = 0.15$, $p = 0.03$), whereas the anxiety level in Wave 2 could not predict that in Wave 3 (model 1: $\beta = 0.09$, $p > 0.05$; model 2: $\beta = 0.08$, $p > 0.05$). Besides, the model 1 revealed that the sleep quality adolescents in Wave 1 could not predicted that in Wave 2 ($\beta = 0.006$, $p > 0.05$), nor sleep quality in Wave 2 could predict the sleep quality in Wave 3 ($\beta = 0.09$, $p = 0.059$). The model 2 suggested the insomnia symptoms in Wave (n) could predict that in Wave (n + 1) (both $p < 0.01$). There were no significant cross-lagged paths in model 1 and model 2 (all $p > 0.05$), suggesting the observed correlations between anxiety and sleep disturbance (poor sleep quality and insomnia symptoms) were primarily due to between-person stability rather than within-person (ie, “A causes B” relations).

The modeling for relationship between depression and sleep quality (model 3, see Fig. 5) fitted well ($\chi^2/df = 6.60$, CFI = 0.99,

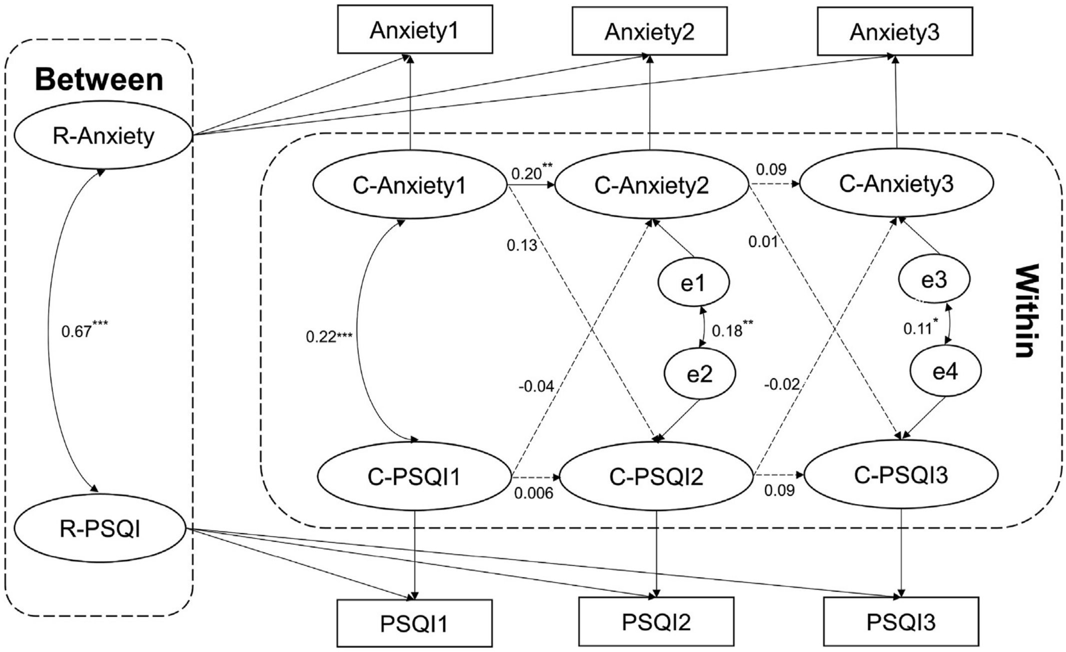

Fig. 4. Model 1: The random intercept cross-lagged effect model between anxiety and sleep quality in adolescents. Note. R was the latent variable at the between-person level (random intercept), and C was the latent variable at the within-person level. * means $p < 0.05$; ** means $p < 0.01$; *** means $p < 0.001$. Solid black lines indicate significant correlations or paths, and dotted black lines indicate insignificant ones.

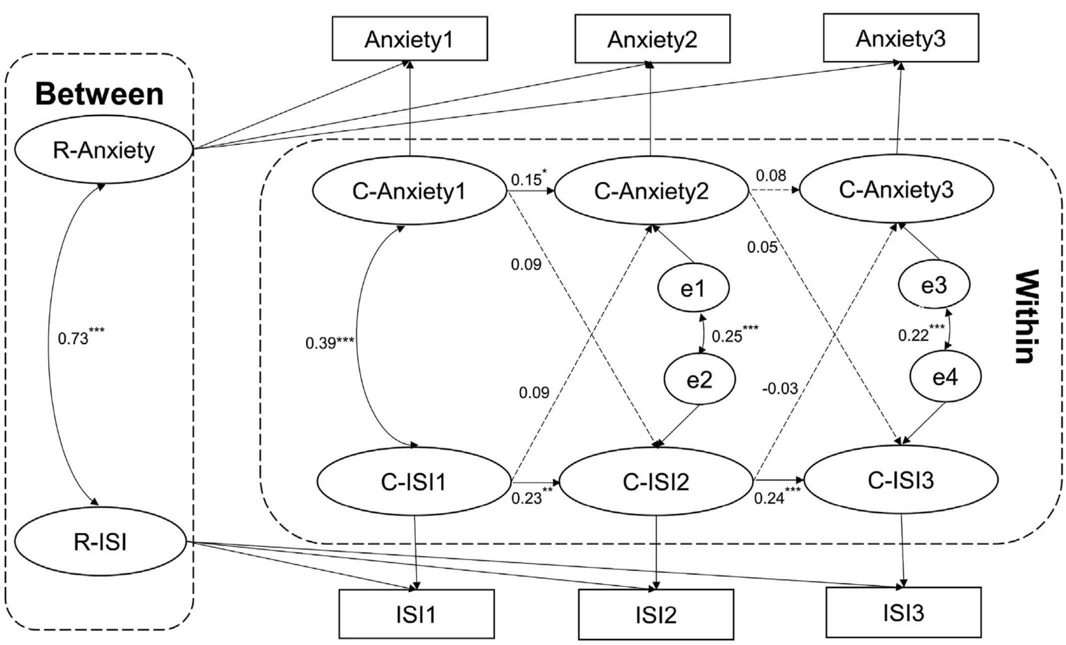

Fig. 5. Model 2: The random intercept cross-lagged effect model between anxiety and insomnia in adolescents. Note. * means $p < 0.05$; ** means $p < 0.01$; *** means $p < 0.001$. Solid black lines indicate significant correlations or paths, and dotted black lines indicate insignificant ones.

TLI = 0.96, RMSEA = 0.08, SRMR = 0.01); also the model of depression and insomnia fitted well (model 4, see Fig. 6) ($\chi^2/df = 13.52$, CFI = 0.99, TLI = 0.94, RMSEA = 0.12, SRMR = 0.01). At the between-person level, the depression level positively associated with poor sleeper (r = 0.69, $p < 0.001$) and insomnia (r = 0.78, $p < 0.001$). At the within-person level, both the model 3 and model 4 suggested the depression level of adolescents in Wave (n) could predict that in Wave (n + 1) (all $p < 0.01$). However, the sleep quality in Wave (n) could not predict that in Wave (n + 1) in model 3 (both $p > 0.05$), while the insomnia scores in Wave (n) could predict the insomnia scores in Wave (n + 1) in model 4 (both $p < 0.01$). It's notable that the depression level in Wave 1 could predict sleep quality ($\beta = 0.26$, $p < 0.001$) and insomnia ($\beta = 0.17$, $p = 0.01$) in Wave 2, and the depression level in Wave 2 could predict sleep quality ($\beta = 0.14$, $p = 0.03$) and insomnia ($\beta = 0.17$, $p = 0.02$) in Wave 3. However, the sleep quality of Wave (n) could not predict the depression level in Wave (n + 1), nor did insomnia of wave (n) (both $p > 0.05$).

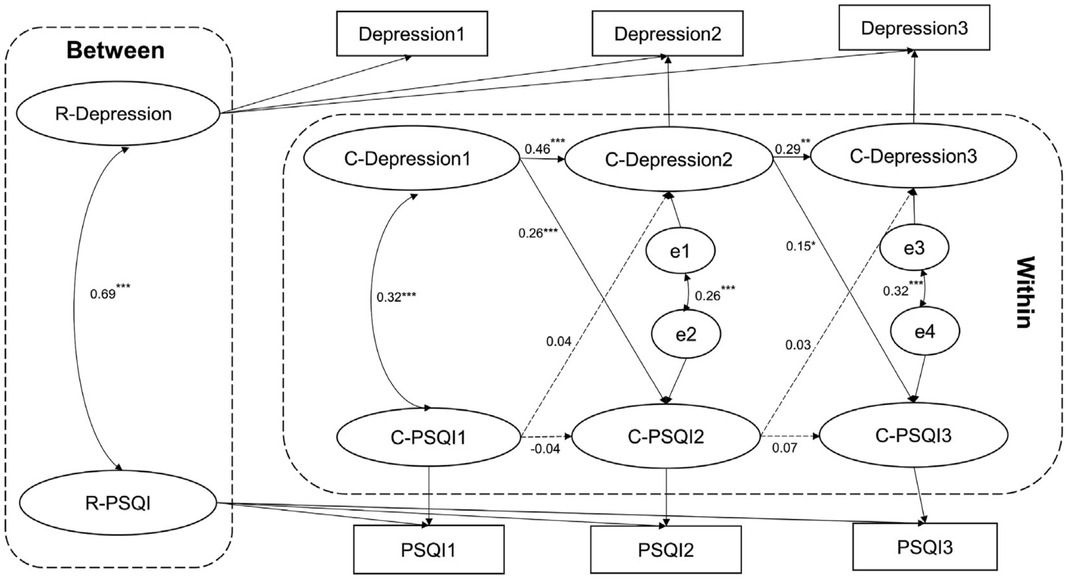

Fig. 6. Model 3: The random intercept cross-lagged effect model between depression and sleep quality in adolescents. Note. * means $p < 0.05$; ** means $p < 0.01$; *** means $p < 0.001$. Solid black lines indicate significant correlations or paths, and dotted black lines indicate insignificant ones.

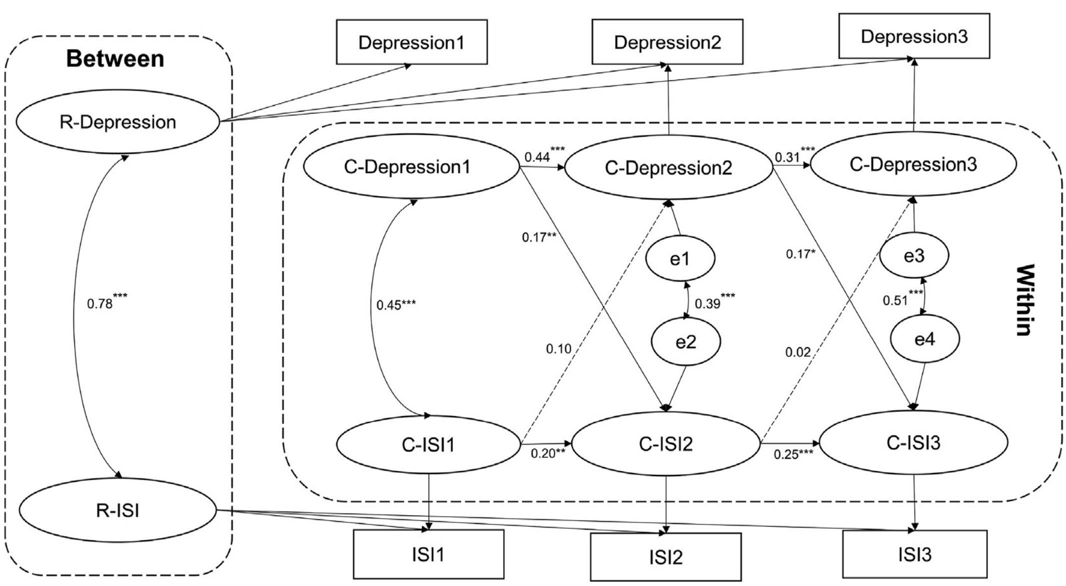

Fig. 7. Model 4: The random intercept cross-lagged effect model between depression and insomnia in adolescents. Note. * means $p < 0.05$; ** means $p < 0.01$; *** means $p < 0.001$. Solid black lines indicate significant correlations or paths, and dotted black lines indicate insignificant ones.

4. Discussion

Earlier COVID-19 studies have reported that the pandemic caused widespread impacts on mental health and sleep in the general population. The current longitudinal follow-up study has conducted an effort to investigate the development of mental heal and sleep outcomes in adolescents before, during, and after the COVID-19 epidemic and further explore how mental health and sleep change and interact across three measurements.

The findings revealed that the COVID-19 epidemic yielded significant changes in sleep and chronotype. In contrast, the prevalence of anxiety, depression, insomnia symptoms, and poor sleeper in adolescents were decreased during the home confinement compared to those before the pandemic. Besides, the gender and chronotype prior to the epidemic played a moderator role in the COVID-19 epidemic-induced mental problems and sleep disturbances. Though the sleep disturbance as assessed with PSQI and insomnia symptoms were positively associated with the symptoms of anxiety and depression during three Waves; a unidirectional relationship between depression and sleep quality was revealed; a higher depression level of the pre-test ($Wave_N$) led to lower sleep quality and more insomnia symptoms at follow-ups (Wave $n + 1$). The results of the current study shedding light on points that governments and health authorities should consider implementing a follow-up on the mental health care and sleep problem intervention of adolescents during the epidemic.

4.1. Change of mental health and sleep across the three waves

In the current study, the home confinement due to the COVID-19 outbreak significantly changed adolescents' sleep behavior and chronotype. Specifically, the adolescents had delayed bedtime and wake-up time by 0.5 h and 1.15 h, respectively, and increased sleep duration of 0.4 h during home confinement (Wave 2). These findings were in line with those from the study by Genta, Rodrigues Neto [30], reporting that during the pandemic, high school students delayed sleep onset and slept offset in 1.5 h and 2.0 h, respectively. Besides, our findings also revealed that adolescents had longer sleep duration, shorter sleep latency, and advanced chronotypes during the home confinement than before the epidemic. These home isolation-induced sleep benefits were also occasionally reported in adults [28,32] and adolescents [29,30] in earlier COVID-19 studies. For instance, Becker, Dvorsky [29] demonstrated that adolescents aged between 15 and 17 slept longer and experienced less daytime sleepiness during lockdown weekdays. These findings could be partly explained by the fact that without the restriction of onset hours for school during the home isolation period, the sleep-wake schedule would develop more closely aligned to their endogenous circadian rhythm for adolescents [68].

Our findings also showed that the prevalence of anxiety, depression, and insomnia symptoms, poor sleeper significantly differed among the three waves. However, the highest prevalence of anxiety, depression, insomnia symptom, and the worst sleep quality were observed before the COVID-19 outbreak that was out of our expectation. Except for the anxiety, these symptoms continued to decline during home confinement (Wave 2) and after the lockdown (Wave 3). The present results are in line with some previous studies [69,70]; a recent meta-analysis of longitudinal studies on the relationship between COVID-19 lockdowns and mental health even reported that the COVID-19 lockdown had subtle impacts on mental health symptoms [69]. Gao and Scullin [70] reported that average sleep quality was unaffected or even improved in the early stage of pandemic. However, these findings contradicted the earlier COVID studies that suggested that quarantine would lead to detrimental effects on psychosocial health in adults [17,71–73]. The group difference might partly explain these inconsistent findings between the earlier COVID-19 studies and the current one. The participants employed in the current study were all adolescent students who were isolated at home longer than other groups (ie, their parents or medical workers), and neither themselves nor their relatives had been infected. Thus, the adolescents would experience less influence of the COVID-19 epidemic. Meanwhile, although the adolescents were still in quarantine in Wave 2, the epidemic had been effectively controlled, especially in the providence where the participants lived (1378 confirmed cases of COVID-19, 52 existing confirmed cases). The positive perception of the epidemic's severity and confidence in the epidemic control was associated with reduced depressive symptoms and increased wellbeing [74]. Besides, the higher prevalence of anxiety, depression, and poor sleeper in Wave 1 could also be due to the higher academic pressure. Previous studies reported that higher pressure would induce disturbance of mental health and sleep [75–78]. In the current study, the first measurement was administered close to the students' final exams, which might result in higher stress to the students.

4.2. Potential risk factors of mental health and sleep quality

The current findings revealed a moderator role of chronotype and gender in the impacts of the COVID-19 epidemic on mental health and sleep. Participants who were evening type showed a significantly higher level of anxiety and depression, lower sleep quality, and more insomnia than intermediate and morning types. Previous research even reported that late chronotype was associated with increased risk for depression and more sleep disturbances in adolescents [79–81] and adults [82,83]. For example, Eid, Bou Saleh [79] reported that the evening-type was also associated with an increased risk of having emotional and behavioral problems in adolescents [79]. Meanwhile, the study of Li, Chan [81] demonstrated that insomnia symptoms were more prevalent in adolescents of evening-type (52%) than those of intermediate-type (34.3%) and morning-type (18.0%). Besides, the findings also showed that girls had significantly higher depression scores than boys, while the gender difference was not revealed in anxiety level. Girls also had more severe sleep problems than boys, showing significantly lower sleep quality and more insomnia symptoms. The current findings are consistent with several studies reporting that adolescent girls were more likely to experience anxiety, depressive symptoms, and sleep disturbance during the epidemic [44,53,84,85] or under normal circumstances [86–88].

4.3. The relationship between mental health levels and sleep status across waves

Our findings revealed that the severity of anxiety and depression were significantly positively correlated with poor sleep quality and insomnia regardless of the Waves. Consistent with the results of the correlation analysis, the results of RI-CLPM also revealed a significant between-person relationship between the “traits” of mental problems and sleep disturbances. Specifically, adolescents with high levels of anxiety and depression showed more sleep problems across measurement waves. In turn, adolescents with more sleep problems also showed higher levels of anxiety and depression during the three waves. Yet, this case was not true for the adolescents who experienced a lower level of anxiety and depression. These findings were comparable to the previous studies, which revealed a strong association and frequent comorbidity between sleep disturbance and mental health problems (including anxiety and depression) in adolescents during the non-epidemic period [85–87] and also the epidemic period [5,19,31,88–90].

After controlling for the between-person trait effects, our results also showed that those adolescents with higher depression and insomnia scores in wave 1 exhibited higher scores at follow-ups. These findings correspond with the literature suggesting that the previous subclinical symptoms of depression and insomnia were stable and predictive of subsequent depressive disorders and sleep disturbance [39,89]. Most importantly, the depression level in previous waves had a positive predictive effect on poor sleep and insomnia symptoms in the subsequent Waves. However, pre-test anxiety was not a predictor of sleep disturbance at follow-ups. These findings were in line with non-epidemic studies on the longitude relationship between depressive/anxiety symptoms and sleep outcomes [38,90]. For instance, Doane, Gress-Smith [90] reported that depressive symptoms of wave 1 (Spring of senior year of high school) were associated with subsequent subjective and objective sleep problems in wave 2 (fall of their first year of college), but not vice versa. In contrast, a few studies even revealed a bidirectional impact between depression and sleep disturbances [91–93] as well as the unidirectional impact of sleep disturbance to later mental illness [39,41,42,94]. For instance, Alvaro, Roberts [91] revealed that insomnia symptoms at baseline predicted symptoms of depression at follow-up in adolescents (aged 12–18) and vice-versa. Besides, a twin study revealed that late bedtime and short sleep duration could predict subsequent development of depression and anxiety, including suicidal or self-injury risk [94].

These inconsistencies of findings between previous studies and the current one might be partly explained by the differential population employed. All participants in the current study were adolescent students, while the adult or the general population were recruited in these studies, reporting a reverse or bidirectional relationship between depression and sleep disturbance [94,95]. In addition, different analytical methods for the cross-lagged relationship of variables among multiple measurements may also contribute to the inconsistent results. Studies demonstrating the predictive roles of baseline incidence of sleep disturbance in the incidence of mental health at follow-ups employed multivariate logistic regressions [91–94], whereas the random-intercept cross-lagged panel model (RI-CLPM) was employed in the current study, in which the variance of the observed score was split into variances due to a between-person stable invariant trait and variance due to within-person fluctuation. Therefore, the positive predictive effect of depression on sleep problems obtained in this study may be more reliable and robust [95]. Notably, the unidirectional effect running from depression to poor sleep quality and insomnia may also be confined to the context – the COVID-19 pandemic. Our results have constructive implications for the intervention of sleep health and mental health in adolescents when the global epidemic is still severe.

This study also has several limitations. First, the sample size of the study is relatively small. Some subjects failed to participate in all three surveys due to personal reasons, resulting in reducing the stability and representativeness of the current findings to a certain extent. Second, the participants selected in this study are all from Southern China, where the epidemic has been well controlled, which limited the application of the findings in other regions, especially those severely affected areas by the COVID-2019 epidemic.

5. Conclusion

In sum, the current study employed a longitudinal design on 831 adolescents and revealed that adolescents' sleep behavior and quality changed significantly during the epidemic. The measurement time (waves), gender, and chronotype played a moderator role in the effects of COVID-19 breakout on mental health and sleep. Meanwhile, a relatively high prevalence of anxiety, depression, poor sleeper, and insomnia symptoms in adolescents occurred before the COVID-19 breakout and during the lockdown. The poor sleep quality and insomnia were associated with increased depression, anxiety scores regardless of waves. Interestingly, the depression symptoms in previous waves could predict sleep quality and insomnia symptoms in subsequent waves. These findings contributed to the current findings suggesting an interaction effect between mental heath and sleep during the COVID-19 epidemic.

Credit author statement

Yun Li: Methodology, Software, Investigation, Formal analysis, Writing – Original draft preparation, Writing – Review & Editing. **Ying Zhou**: Software, Writing – Review & Editing. **TaoTao Ru**: Supervision, Conceptualization, Methodology, Validation, Writing – Review & Editing. **Jiaxing Liu**: Resources, Data curation, Visualization. **Meiheng He**: Resources, Data curation, Visualization. **Guofu Zhou**: Project administration, Supervision, Funding acquisition.

Acknowledgement

This work was supported by the Science and Technology Program of Guangzhou [grant numbers 2019050001], Guangdong Provincial Key Laboratory of Optical Information Materials and Technology [grant numbers 2017B030301007], National Center for International Research on Green Optoelectronics, MOE International Laboratory for Optical Information Technologies and the 111 Project.

Conflict of interest

None declared.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.07.008.

References

[1] Anderson RM, Heesterbeek H, Klinkenberg D, et al. How will country-based mitigation measures influence the course of the COVID-19 epidemic? Lancet 2020;395:931–4.
[2] Krishnamoorthy Y, Nagarajan R, Saya GK, et al. Prevalence of psychological morbidities among general population, healthcare workers and COVID-19 patients amidst the COVID-19 pandemic: a systematic review and meta-analysis. Psychiatry Res 2020;293:113382.
[3] Wang Y, Kala MP, Jafar TH. Factors associated with psychological distress during the coronavirus disease 2019 (COVID-19) pandemic on the predominantly general population: a systematic review and meta-analysis. PLoS One 2020;15:e0244630.
[4] Ministry of Education of China China MoEo. The notice of the leading party members' group of the ministry of education of the communist party of China on the prevention and control of coronavirus pneumonia and the reform and development of education. Ministry of Education of China; 2020.
[5] Zhou SJ, Wang LL, Yang R, et al. Sleep problems among Chinese adolescents and young adults during the coronavirus-2019 pandemic. Sleep Med 2020;74: 39–47.
[6] Zhen R, Zhou X. Predictive factors of public anxiety under the outbreak of COVID-19. Chin J Appl Psychol 2020;26:99–108.
[7] Duan L, Shao X, Wang Y, et al. An investigation of mental health status of children and adolescents in China during the outbreak of COVID-19. J Affect Disord 2020;275:112–8.
[8] Varma P, Junge M, Meaklim H, et al. Younger people are more vulnerable to stress, anxiety and depression during COVID-19 pandemic: a global cross-sectional survey. Prog Neuro Psychopharmacol Biol Psychiatry 2021;109:110236.
[9] Blume C, Schmidt MH, Cajochen C. Effects of the COVID-19 lockdown on human sleep and rest-activity rhythms. Curr Biol 2020;30:R795–7.
[10] Huang Y, Zhao N. Generalized anxiety disorder, depressive symptoms and sleep quality during COVID-19 outbreak in China: a web-based cross-sectional survey. Psychiatry Res 2020;288:112954.
[11] Tighe CA, Dautovich ND, McCrae CS. Daily social contact in relation to sleep: the role of age. Behav Sleep Med 2016;14:311–24.
[12] Sani F, Herrera M, Wakefield JR, et al. Comparing social contact and group identification as predictors of mental health. Br J Soc Psychol 2012;51:781–90.
[13] Vancampfort D, Van Damme T, Stubbs B, et al. Sedentary behavior and anxiety-induced sleep disturbance among 181,093 adolescents from 67 countries: a global perspective. Sleep Med 2019;58:19–26.
[14] Kalmbach DA, Fang Y, Arnedt JT, et al. Effects of sleep, physical activity, and shift work on daily mood: a prospective mobile monitoring study of medical interns. J Gen Intern Med 2018;33:914–20.
[15] Hale L, Guan S. Screen time and sleep among school-aged children and adolescents: a systematic literature review. Sleep Med Rev 2015;21:50–8.
[16] van der Schuur WA, Baumgartner SE, Sumter SR. social media use, social media stress, and sleep: examining cross-sectional and longitudinal relationships in adolescents. Health Commun 2019;34:552–9.
[17] Gualano MR, Lo Moro G, Voglino G, et al. Effects of Covid-19 lockdown on mental health and sleep disturbances in Italy. Int J Environ Res Public Health 2020;17:4779.
[18] Zhang X, Zhu W, Kang S, et al. Association between physical activity and mood states of children and adolescents in social isolation during the COVID-19 epidemic. Int J Environ Res Public Health 2020;17.
[19] Fegert JM, Vitiello B, Plener PL, et al. Challenges and burden of the Coronavirus 2019 (COVID-19) pandemic for child and adolescent mental health: a narrative review to highlight clinical and research needs in the acute phase and the long return to normality. Child Adolesc Psychiatry Ment Health 2020;14:20.
[20] Chen F, Zheng D, Liu J, et al. Depression and anxiety among adolescents during COVID-19: a cross-sectional study. Brain Behav Immun 2020;88:36–8.
[21] Lavigne-Cerván R, Costa-López B, Juárez-Ruiz de Mier R, et al. Consequences of COVID-19 confinement on anxiety, sleep and executive functions of children and adolescents in Spain. Front Psychol 2021;12:334.
[22] Kılınçel Ş, Kılınçel O, Muratdağı G, et al. Factors affecting the anxiety levels of adolescents in home-quarantine during COVID-19 pandemic in Turkey. Asia Pac Psychiatry 2021;13:e12406.

[23] O'Sullivan K, Clark S, McGrane A, et al. A qualitative study of child and adolescent mental health during the COVID-19 pandemic in Ireland. Int J Environ Res Public Health 2021;18:1062.
[24] Barendse M, Flannery J, Cavanagh C, et al. Longitudinal change in adolescent depression and anxiety symptoms from before to during the COVID-19 pandemic: an international collaborative of 12 samples. PsyArXiv 2021 February 3:0–38.
[25] Magson NR, Freeman JY, Rapee RM, et al. Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. J Youth Adolesc 2021;50:44–57.
[26] Franceschini C, Musetti A, Zenesini C, et al. Poor sleep quality and its consequences on mental health during the COVID-19 lockdown in Italy. Front Psychol 2020:11.
[27] Marelli S, Castelnuovo A, Somma A, et al. Impact of COVID-19 lockdown on sleep quality in university students and administration staff. J Neurol 2021;268:8–15.
[28] Leone MJ, Sigman M, Golombek DA. Effects of lockdown on human sleep and chronotype during the COVID-19 pandemic. Curr Biol 2020;30:R930–1.
[29] Becker SP, Dvorsky M, Breaux R, et al. Prospective examination of adolescent sleep patterns and behaviors before and during COVID-19. Sleep 2021;zsab054:1–11.
[30] Genta FD, Rodrigues Neto GB, Velletri Sunfeld JP, et al. COVID-19 pandemic impact on sleep habits, chronotype and health-related quality of life among high school students: a longitudinal study. J Clin Sleep Med 2021;17(7):1371–7.
[31] Gruber R, Saha S, Somerville G, et al. The impact of COVID-19 related school shutdown on sleep in adolescents: a natural experiment. Sleep Med 2020;76:33–5.
[32] Sinha M, Pande B, Sinha R. Impact of COVID-19 lockdown on sleep-wake schedule and associated lifestyle related behavior: a national survey. J Public Health Res 2020;9:1826.
[33] Hyun S, Hahm HC, Wong GTF, et al. Psychological correlates of poor sleep quality among US young adults during the COVID-19 pandemic. Sleep Med 2021;78:51–6.
[34] Stanton R, To QG, Khalesi S, et al. Depression, anxiety and stress during COVID-19: associations with changes in physical activity, sleep, tobacco and alcohol use in Australian adults. Int J Environ Res Public Health 2020;17.
[35] Yuksel D, McKee GB, Perrin PB, et al. Sleeping when the world locks down: correlates of sleep health during the COVID-19 pandemic across 59 countries. Sleep Health 2021;7:134–42.
[36] Navarro-Soria I, Real-Fernández M, Juárez-Ruiz de Mier R, et al. Consequences of confinement due to COVID-19 in Spain on anxiety, sleep and executive functioning of children and adolescents with ADHD. Sustainability 2021;13:2487.
[37] Tochigi M, Usami S, Matamura M, et al. Annual longitudinal survey at up to five time points reveals reciprocal effects of bedtime delay and depression/anxiety in adolescents. Sleep Med 2016;17:81–6.
[38] Goldman-Mellor S, Gregory AM, Caspi A, et al. Mental health antecedents of early midlife insomnia: evidence from a four-decade longitudinal study. Sleep 2014;37:1767–75.
[39] Goldstone A, Javitz HS, Claudatos SA, et al. Sleep disturbance predicts depression symptoms in early adolescence: initial findings from the adolescent brain cognitive development study. J Adolesc Health 2020;66:567–74.
[40] Hayley AC, Skogen JC, Sivertsen B, et al. Symptoms of depression and difficulty initiating sleep from early adolescence to early adulthood: a longitudinal study. Sleep 2015;38:1599–606.
[41] Liu BP, Wang XT, Liu ZZ, et al. Depressive symptoms are associated with short and long sleep duration: a longitudinal study of Chinese adolescents. J Affect Disord 2020;263:267–73.
[42] Roberts RE, Duong HT. Is there an association between short sleep duration and adolescent anxiety disorders? Sleep Med 2017;30:82–7.
[43] Hernández-López M, Cepeda-Benito A, Díaz-Pavón P, et al. Psychological inflexibility and mental health symptoms during the COVID-19 lockdown in Spain: a longitudinal study. J Context Behav Sci 2021;19:42–9.
[44] Breslau J, Finucane ML, Locker AR, et al. A longitudinal study of psychological distress in the United States before and during the COVID-19 pandemic. Prev Med 2021;143:106362.
[45] Fernández-Abascal EG, Martín-Díaz MD. Longitudinal study on affect, psychological well-being, depression, mental and physical health, prior to and during the COVID-19 pandemic in Spain. Personality and Individual Differences 2021:172.
[46] Wang C, Pan R, Wan X, et al. A longitudinal study on the mental health of general population during the COVID-19 epidemic in China. Brain Behav Immun 2020;87:40–8.
[47] Pan K-Y, Kok AAL, Eikelenboom M, et al. The mental health impact of the COVID-19 pandemic on people with and without depressive, anxiety, or obsessive-compulsive disorders: a longitudinal study of three Dutch case-control cohorts. Lancet Psychiatry 2020;8(2):121–9.
[48] Pierce M, Hope H, Ford T, et al. Mental health before and during the COVID-19 pandemic: a longitudinal probability sample survey of the UK population. Lancet Psychiatry 2020;7:883–92.
[49] Markovic A, Mühlematter C, Beaugrand M, et al. Severe effects of the COVID-19 confinement on young children's sleep: a longitudinal study identifying risk and protective factors. J Sleep Res 2021:e13314.
[50] Salfi F, Lauriola M, Amicucci G, et al. Gender-related time course of sleep disturbances and psychological symptoms during the COVID-19 lockdown: a longitudinal study on the Italian population. Neurobiol Stress 2020;13:100259.
[51] Daly M, Sutin AR, Robinson E. Longitudinal changes in mental health and the COVID-19 pandemic: evidence from the UK household longitudinal study. Psychol Med 2020:1–10.
[52] Hafstad GS, Sætren SS, Wentzel-Larsen T, et al. Adolescents' symptoms of anxiety and depression before and during the Covid-19 outbreak – a prospective population-based study of teenagers in Norway. Lancet Reg Health Europe 2021;5:100093.
[53] Lin LY, Wang J, Ou-Yang XY, et al. The immediate impact of the 2019 novel coronavirus (COVID-19) outbreak on subjective sleep status. Sleep Med 2020;77:348–54.
[54] Petrov M, Buman M, Epstein D, et al. 660 chronotype associations with insomnia, depressive symptoms, and changes in sleep and health behaviors during the COVID-19 pandemic. Sleep 2021;44. A258-A.
[55] Bazzani A, Bruno S, Frumento P, et al. Sleep quality mediates the effect of chronotype on resilience in the time of COVID-19. Chronobiol Int 2021:1–10.
[56] Türkoğlu S, Uçar HN, Çetin FH, et al. The relationship between chronotype, sleep, and autism symptom severity in children with ASD in COVID-19 home confinement period. Chronobiol Int 2020;37:1207–13.
[57] Wenjuanxing: Platform for survey design.
[58] Carciofo R, Du F, Song N, et al. Age-related chronotype differences in Chinese, and reliability assessment of a reduced version of the Chinese Morningness Eveningness Questionnaire. Sleep Biol Rhythm 2012;10:310–8.
[59] Wei-Xia L. Validity and reliability of the Chinese version of Morningness/Eveningness Questionnaire-5 items (MEQ-5) in students of technical schools. Chin Ment Health J 2016;30:406–12.
[60] Zung WW. A rating instrument for anxiety disorders. Psychosomatics 1971;12(6):371–9.
[61] Beck AT, Steer RA, Brown GK. Beck depression inventory (BDI-II). Pearson; 1996.
[62] Tsai P-S, Wang S-Y, Wang M-Y, et al. Psychometric evaluation of the Chinese version of the Pittsburgh Sleep Quality Index (CPSQI) in primary insomnia and control subjects. Qual Life Res 2005;14:1943–52.
[63] Morin CM, Belleville G, Bélanger L, et al. The Insomnia Severity Index: psychometric indicators to detect insomnia cases and evaluate treatment response. Sleep 2011;34:601–8.
[64] Hayes AF, Coutts JJ. Use omega rather than Cronbach's alpha for estimating reliability. But…. Commun Methods Meas 2020;14:1–24.
[65] Bates D, Mächler M, Bolker B, et al. Fitting linear mixed-effects models using lme4. 2014. arXiv preprint arXiv:14065823.
[66] Muthén LK, Muthén BO. 1998–2010 Mplus user's guide. Muthén Muthén 2010:39–49.
[67] Podsakoff N. Common method biases in behavioral research: a critical review of the literature and recommended remedies. J Appl Psychol 2003;885:10–1037.
[68] Altena E, Baglioni C, Espie CA, et al. Dealing with sleep problems during home confinement due to the COVID-19 outbreak: practical recommendations from a task force of the European CBT-I academy. J Sleep Res 2020;29:e13052.
[69] Prati G, Mancini AD. The psychological impact of COVID-19 pandemic lockdowns: a review and meta-analysis of longitudinal studies and natural experiments. Psychol Med 2021;51:201–11.
[70] Gao C, Scullin MK. Sleep health early in the coronavirus disease 2019 (COVID-19) outbreak in the United States: integrating longitudinal, cross-sectional, and retrospective recall data. Sleep Med 2020;73:1–10.
[71] Luo M, Guo L, Yu M, et al. The psychological and mental impact of coronavirus disease 2019 (COVID-19) on medical staff and general public – a systematic review and meta-analysis. Psychiatry Res 2020;291:113190.
[72] Vindegaard N, Benros ME. COVID-19 pandemic and mental health consequences: systematic review of the current evidence. Brain Behav Immun 2020;89:531–42.
[73] Ali A, Siddiqui AA, Arshad MS, et al. Effects of COVID-19 pandemic and lockdown on lifestyle and mental health of students: a retrospective study from Karachi, Pakistan. Ann Médico-psychol Rev Psychiatr 2021. Elsevier.
[74] Lu H, Nie P, Qian L. Do quarantine experiences and attitudes towards COVID-19 affect the distribution of mental health in China? A quantile regression analysis. Appl Res Qual Life 2020:1–18.
[75] Zhang WJ, Yan C, Shum D, et al. Responses to academic stress mediate the association between sleep difficulties and depressive/anxiety symptoms in Chinese adolescents. J Affect Disord 2020;263:89–98.
[76] Yan Y-W, Lin R-M, Su Y-K, et al. The relationship between adolescent academic stress and sleep quality: a multiple mediation model. SBP 2018;46:63–77.
[77] Deb S, Strodl E, Sun J. Academic stress, parental pressure, anxiety and mental health among Indian high school students. Int J Psychol Behav Sci 2015;5:26–34.
[78] Liu Y, Lu Z. Chinese high school students' academic stress and depressive symptoms: gender and school climate as moderators. Stress Health 2012;28:340–6.
[79] Eid B, Bou Saleh M, Melki I, et al. Evaluation of chronotype among children and associations with BMI, sleep, anxiety, and depression. Front Neurol 2020;11:416.

[80] Van den Berg JF, Kivela L, Antypa N. Chronotype and depressive symptoms in students: an investigation of possible mechanisms. Chronobiol Int 2018;35:1248–61.
[81] Li SX, Chan NY, Man Yu MW, et al. Eveningness chronotype, insomnia symptoms, and emotional and behavioural problems in adolescents. Sleep Med 2018;47:93–9.
[82] Bauducco S, Richardson C, Gradisar M. Chronotype, circadian rhythms and mood. Curr Opin Psychol 2020;34:77–83.
[83] Au J, Reece J. The relationship between chronotype and depressive symptoms: a meta-analysis. J Affect Disord 2017;218:93–104.
[84] Zhou S-J, Zhang L-G, Wang L-L, et al. Prevalence and socio-demographic correlates of psychological health problems in Chinese adolescents during the outbreak of COVID-19. Eur Child Adolesc Psychiatry 2020:1–10.
[85] Chen F, Zheng D, Liu J, et al. Depression and anxiety among adolescents during COVID-19: a cross-sectional study. Brain Behav Immun 2020;88:36–8.
[86] Wiklund M, Malmgren-Olsson E-B, Öhman A, et al. Subjective health complaints in older adolescents are related to perceived stress, anxiety and gender – a cross-sectional school study in Northern Sweden. BMC Public Health 2012;12:993.
[87] Compas BE, Oppedisano G, Connor JK, et al. Gender differences in depressive symptoms in adolescence: comparison of national samples of clinically referred and nonreferred youths. J Consult Clin Psychol 1997;65:617–26.
[88] Danielsson NS, Harvey AG, MacDonald S, et al. Sleep disturbance and depressive symptoms in adolescence: the role of catastrophic worry. J Youth Adolesc 2013;42:1223–33.
[89] Keenan K, Hipwell A, Feng X, et al. Subthreshold symptoms of depression in preadolescent girls are stable and predictive of depressive disorders. J Am Acad Child Adolesc Psychiatry 2008;47:1433–42.
[90] 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;44:389–404.
[91] Alvaro PK, Roberts RM, Harris JK, et al. The direction of the relationship between symptoms of insomnia and psychiatric disorders in adolescents. J Affect Disord 2017;207:167–74.
[92] Sun Y, Shi L, Bao Y, et al. The bidirectional relationship between sleep duration and depression in community-dwelling middle-aged and elderly individuals: evidence from a longitudinal study. Sleep Med 2018;52:221–9.
[93] Kim J-M, Stewart R, Kim S-W, et al. Insomnia, depression, and physical disorders in late life: a 2-year longitudinal community study in Koreans. Sleep 2009;32:1221–8.
[94] Matamura M, Tochigi M, Usami S, et al. Associations between sleep habits and mental health status and suicidality in a longitudinal survey of monozygotic twin adolescents. J Sleep Res 2014;23:290–4.
[95] Burns RA, Crisp DA, Burns RB. Re-examining the reciprocal effects model of self-concept, self-efficacy, and academic achievement in a comparison of the cross-lagged panel and Random-Intercept cross-lagged panel frameworks. Br J Educ Psychol 2020;90:77–91.