

# Correlation Between Chronotypes and Depressive Symptoms Mediated by Sleep Quality Among Chinese College Students During the COVID-19 Pandemic

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**Purpose:** The COVID-19 pandemic has adversely impacted the mental health of the population. The current study aimed to determine the prevalence of depressive symptoms and sleep disturbances among Chinese college students during the COVID-19 pandemic and investigate the correlations between chronotypes, sleep quality, and depressive symptoms.

**Participants and Methods:** In the current study, 2526 college students responded anonymously to an online questionnaire survey from 26 May 2020 to 20 July 2020. The participants' chronotypes, sleep quality, and depressive symptoms were evaluated using the Chinese version of the Morning and Evening Questionnaire-5 (MEQ-5), Pittsburgh Sleep Quality Index (PSQI), and Patient Health Questionnaire-9 (PHQ-9). Sociodemographic information of the participants was also acquired. Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) 19.0 software, with the mediating effect assessed by Hayes' PROCESS Macro.

**Results:** During the COVID-19 pandemic, the prevalence of depressive symptoms and sleep disturbances among Chinese college students surveyed was 54.95% and 48.18%, respectively. From absolute evening chronotype to absolute morning chronotype, the surveyed college students' chronotypes were negatively correlated with their depressive symptoms. Moreover, the mediation analysis showed that the correlation between chronotypes and depressive symptoms was fully mediated by sleep quality. Eveningness college students with poorer sleep quality were more likely to report higher levels of depressive symptoms.

**Conclusion:** Our findings suggest that during the COVID-19 pandemic, delayed circadian preference (ie, eveningness) may be linked to worse depressive symptoms among Chinese college students, and call for more attention to the sleep quality of Chinese college students as sleep quality fully mediated the correlation between chronotypes and depressive symptoms among them. Reasonable adjustment in bedtime/circadian preference and improvement in sleep quality may help to reduce the prevalence and severity of depressive symptoms among Chinese college students.

**Keywords:** COVID-19, chronotype, depressive symptom, sleep quality, college student

## Introduction

Serious public health emergencies are major stressors in society,<sup>1</sup> which may cause mental problems such as acute stress disorder, post-traumatic stress disorder, depression, and anxiety.<sup>2</sup> The novel coronavirus disease 2019 (COVID-19) pandemic, which initially appeared in Wuhan, Hubei Province, China at the end of 2019, has been an unexpected, large-scale, public health event that disrupted communities and caused death, destruction and trauma, and aroused widespread concern of the world.<sup>3</sup> The outbreak of the COVID-19 pandemic not only caused particularly large public health problems, but also severely disrupted most people's daily life and affected their mental health globally.<sup>3,4</sup>

The COVID-19 pandemic has caused psychological problems and sleep problems in different populations, including healthcare professionals, COVID-19 infected individuals, and the general population.<sup>5–10</sup> Development of symptoms in

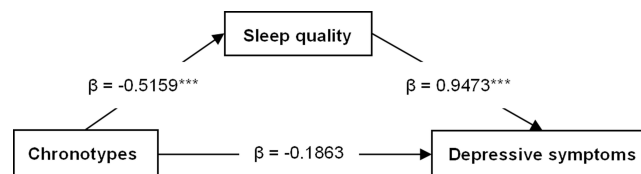
previously healthy individuals, new episodes in those with predisposition to mental disorders and development of symptoms that do not meet diagnostic criteria, are three common ways that the COVID-19 pandemic affects the individuals' mental conditions.<sup>11</sup> In addition, the level of mental health problems varies depending on the stage of the pandemic, as well as nations, races, various socioeconomic factors and demographic factors such as gender, age, residence, work category and economic condition.<sup>11</sup> The epidemic nature of COVID-19, with very high rates of infection and relatively high mortality, and resultant social restrictions implemented by governments around the world have caused the affected population to naturally and easily suffer from psychological problems and sleep disturbances.<sup>12–15</sup> The sudden onset of a threatening illness with very high rate of infection puts great pressure on the population and results in a substantial change in lifestyle, which should be a huge stressor to develop psychological and sleep problems.<sup>5–10,16</sup> Fear of COVID-19, as indicated in several studies, may be a key factor that associated with various mental health problems. Reducing fear of COVID-19 and proper prevention of COVID-19 infection are essential to improve mental conditions of the population.<sup>9</sup>

The psychological toll of COVID-19 among college students should be a focal point in COVID-19 researches. As a common measure to prevent and control the COVID-19 pandemic, the learning style of most college students has been switched from the face-to-face to online system.<sup>17,18</sup> Besides, campus activities have been restricted, held over, or canceled.<sup>19</sup> This transformation in lifestyle and the threat of infection may lead to a heightened vulnerability of affected individuals to depressive symptoms.<sup>18</sup> College students affected may encounter negative emotions including depression, anxiety, anger, boredom, and loneliness, which may contribute to a poor academic performance.<sup>15,20,21</sup>

In addition to negative emotions, sleep disturbances are another prominent mental problem among college students affected by the COVID-19 pandemic.<sup>8,21–23</sup> There are different obstacles for individuals living in the modern world to achieve good sleep.<sup>24</sup> Unfortunately, the COVID-19 pandemic has significantly worsened the sleep quality, increased the prevalence of sleep disturbances and promoted changes in the sleep pattern in various populations.<sup>10,25</sup> Numerous studies on sleep disturbances were conducted during the COVID-19 pandemic, and the estimated prevalence of sleep problems was 41.16% among college students.<sup>10</sup> The high prevalence of sleep problems among college students may be explained by the following factors: changes in sleep-wake habits (eg, delayed bedtime, lights off time, and sleep onset time), lockdown, fear of COVID-19, and other related psychological distress.<sup>8,10,26–28</sup> Interestingly, single-parent family and experience of domestic violence were found to increase the risk of poor sleep quality during the COVID-19 pandemic among Chinese college students, while exercises may improve sleep quality of the college students.<sup>29</sup>

The prevalence of depression/depressive symptoms and sleep disturbances among college students was high even before the emergence of COVID-19 pandemic. An international meta-analysis demonstrated that the prevalence of depression among college students worldwide was as high as 30.6%.<sup>30</sup> Among the Chinese college students, the detection rate of depressive symptoms is approximately 24.71%.<sup>31</sup> As reported, 12.92% to 52.84% of college students experienced sleep disturbances, especially insomnia.<sup>32–34</sup> In addition, numerous studies have shown a strong correlation between poor sleep and depression/depressive symptoms. Approximately 70% of depressed patients have symptoms of insomnia.<sup>35</sup> Furthermore, the prevalence of depression is three to four times higher in patients with insomnia disorder compared with individuals without insomnia disorder.<sup>36</sup> A longitudinal study involving a 4-year follow-up of subjects noted that the risk of new-onset depression was 8.48-fold higher and the risk of new-onset depression accompanied by anxiety was 17.98-fold higher in insomnia group compared with the non-insomnia group.<sup>37</sup> Similarly, a 1-year follow-up study of secondary school students in China showed that baseline insomnia symptoms in secondary school students could increase the risk of developing depressive symptoms in 1 year, and baseline depressive symptoms could predict the severity of insomnia symptoms at 1-year time point as well.<sup>38</sup> These findings suggest a complex bidirectional pathological relationship between insomnia symptoms and depressive symptoms in adolescents, which is consistent with findings of other studies.<sup>39,40</sup> However, the specific mechanisms through which poor sleep leads to a high prevalence of depression/depressive symptoms remain unknown.

Alteration in circadian preference is common seen among college students, which can have an adverse effect on their health.<sup>41</sup> After the outbreak of COVID-19, the sleep patterns of many college students have been disrupted.<sup>10,26–28</sup> Both delayed or disorganized circadian rhythm may be linked with depressive symptoms in young adults with unipolar depressive disorder.<sup>42</sup> However, the nature of circadian rhythm disturbance in depressive symptoms remains unclear.



**Figure 1** Basic hypothesis of the present study.

**Notes:** Significance levels are marked as \*\*\* for  $P < 0.001$ .

Whether circadian rhythm or chronotypes are directly or indirectly linked to depressive symptoms among college students is currently unknown. In particular, to the best of our knowledge, few studies have reported the mediating factors and effect of chronotypes or changes in sleep patterns of college students on depressive symptoms during the COVID-19 pandemic. Thus, it is essential to explore the mechanisms of chronotypes' influence on depressive symptoms (eg, mediating factors) among college students.

Notably, disturbance in the sleep-wake cycle or circadian rhythm is an important contributing factor to the onset of insomnia symptoms.<sup>43</sup> Therefore, based on the above-mentioned facts, we hypothesized that during the COVID-19 Pandemic, the prevalence of depressive symptoms and sleep disturbances among Chinese college students would also be significantly higher than that before the emergence of COVID-19 pandemic, and there may be complex correlations between chronotypes, sleep disturbances and depressive symptoms of college students (Figure 1).

We conducted a cross-sectional study based on questionnaires administered online in Chinese college students between 26 May 2020 and 20 July 2020. One aim of the present study was to determine the prevalence of depressive symptoms and sleep disturbances among Chinese college students during the COVID-19 pandemic. Moreover, few studies have examined chronotypes, sleep quality and depressive symptoms in one model. Another aim of the present study was to investigate the correlations between chronotypes, sleep quality and depressive symptoms among the participants surveyed. Our findings may provide additional evidence for further understanding the correlation between chronotypes and depressive symptoms, and provide a further reference for mental health interventions for college students affected by COVID-19 pandemic.

## Materials and Methods

### Study Procedure and Participants

An online questionnaire survey was conducted from 26 May 2020 to 20 July 2020. Sets of web-based self-reported questionnaires were designed on an online questionnaire platform to collect data regarding sleep status and depressive symptoms via a link that could be shared on smartphones. The participants were asked to answer the questionnaire anonymously. Detailed and specific instructions were given to ensure the validity and accuracy of data. To ensure the rigor of the study, some items were scored in reverse, and only one set of answers was accepted from each internet protocol address.

Using the random whole-group sampling method, participants were recruited from colleges and universities in Guangdong province, China. Each participant took approximately 15 minutes to complete the questionnaires. No monetary compensation was provided for participating in the study.

All participants gave informed consent electronically before completing the questionnaires. The present study complies with the Declaration of Helsinki, and the study protocol was approved by the Human Research and Ethics Committee of the First Affiliated Hospital of Jinan University, Guangzhou, China (approval number: KY-2023-126).

### Questionnaires and Measurements

#### General Information Questionnaire

Sociodemographic information including sex, age, height, weight, college major, and place of residence were obtained for each participant. History of physical illness and mental disorders, alcohol consumption, and smoking status were also recorded.

All participants completed the Chinese versions of the following questionnaires.

### Morning and Evening Questionnaire-5 (MEQ-5)

The MEQ-5 is used for subjective assessment of an individual's chronotype, with a total score range of 4 to 25.<sup>44,45</sup> The proposed delimitation scores are as follows: 4–7 for absolute evening chronotype, 8–11 for moderate evening chronotype, 12–17 for intermediate chronotype, 18–21 for moderate morning chronotype, and 22–25 for absolute morning chronotype.

### Pittsburgh Sleep Quality Index (PSQI)

The PSQI consists of 19 self-rated and five other-rated items, which are designed to evaluate subjective sleep quality over the last 30 consecutive days. The total score of the PSQI ranges from 0 to 21, the higher the total score, the worse the sleep quality.<sup>46</sup>

### Patient Health Questionnaire-9 (PHQ-9)

The PHQ-9 is a 4-point scale, with a total score ranging from 0 to 27. A total score < 5 indicates no depressive symptoms; 5–9, mild depressive symptoms; 10–14, moderate depressive symptoms; 15–19, moderate to severe depressive symptoms; and 20–27, severe depressive symptoms. The PHQ-9 has good reliability, with 93.33% sensitivity, and 96.83% specificity when used to assess depression in adolescents.<sup>47,48</sup>

All the above measures used in the present study had been translated into Chinese with standard translation procedure to ensure their linguistic validity, and had been widely used in Chinese population studies.<sup>48–50</sup> In order to control the common method bias, anonymous and reverse scoring methods were used in the present questionnaire survey.

## Statistical Analyses

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) 19.0 software. All variables were standardized prior to being analyzed. The one-sample Kolmogorov–Smirnov test was used to assess whether data was of normal distribution. The Harman's single-factor method was used to test the common method bias.<sup>51</sup> Descriptive analysis was used to measure the prevalence of depressive symptoms and sleep disturbances among the surveyed college students. Correlation analysis was carried out to analyze the correlations between chronotypes, sleep quality, and depressive symptoms of the participants.

To estimate the mediating effect of sleep quality on the correlation between chronotypes and depressive symptoms, the mediation model with one mediator (Model 4) and bootstrap analyses were conducted using SPSS Hayes' PROCESS Macro v2.16.3.<sup>52,53</sup> Bootstrapping was done with 5000 resamples and bias-corrected 95% confidence intervals (CIs) were used to investigate the indirect effects.

Known variables or those that could likely affect the statistical results were included in the analyses as control variables. *P* value < 0.05 was considered statistically significant.

## Results

### Characteristics of the Participants

A total of 2552 college students from a variety of college majors responded to the survey, 26 of whom were excluded as they did not complete all the questionnaires. The final sample consisted of 2526 participants, aged  $20.72 \pm 3.55$  years, among which 1535 (60.77%) were female students. The distribution according to college majors of the participants was as follows: 1089 (43.11%) majored in liberal arts, 898 (35.55%) majored in science, 316 (12.51%) majored in natural science, and 223 (8.83%) majored in art.

### Common Method Bias

All data for analysis in this study were obtained through subjective self-report, which may have a common method bias. The result of Harman's single-factor test showed that a total of 6 factors had eigenvalues greater than 1, and the first factor explained only 27.97% of the variance, which was much less than 40%, indicating that there was no significant common method bias in the present study.

## Prevalence of Depressive Symptoms and Sleep Disturbances Among the College Students Surveyed During the COVID-19 Pandemic

Among the surveyed college students, 54.95% (1388/2526) had varying degrees of depressive symptoms and 48.18% (1217/2526) had varying degrees of sleep disturbances during the COVID-19 pandemic.

### Chronotypes of the College Students Surveyed

According to the MEQ-5 total score, chronotypes of the college students surveyed can be classified as follows: 0.83% (21/2526) were absolute evening chronotype, 21.22% (536/2526) were moderate evening chronotype, 74.98% (1894/2526) were intermediate chronotype, 2.73% (69/2526) were moderate morning chronotype, and 0.24% (6/2526) were absolute morning chronotype. When performing statistical analyses, we labeled absolute evening chronotype as 1, moderate evening chronotype as 2, intermediate chronotype as 3, moderate morning chronotype as 4, and absolute morning chronotype as 5.

### Descriptive Statistics and Correlation Analyses of Each Variable

The mean, standard deviation, and correlation analysis results of each variable are shown in Table 1. The results of correlation analysis showed statistical correlations between the chronotypes (assessed by MEQ-5), sleep quality (assessed by PSQI), and severity of depressive symptoms (assessed by PHQ-9) among college students surveyed, which met the condition of the mediating effect test. College students surveyed with later chronotypes (ie, eveningness) and poorer sleep quality were more likely to report higher levels of depressive symptoms.

### Analysis of the Mediating Effect of Sleep Quality on Correlation Between Chronotypes and Depressive Symptoms Among the College Students Surveyed

The mediating effect test was conducted by considering the surveyed college students' chronotypes (labeled as 1–5) as the independent variable, depressive symptoms (PHQ-9 total scores) as the dependent variable, and sleep quality (PSQI total scores) as the mediating variable. Variables including sex and age, which could likely affect the statistical results, were included in the analyses as control variables. We firstly examined the effect of chronotypes on depressive symptoms without considering any mediating effect. Then we took the mediating effect of sleep quality into account, when examining the effect of chronotypes on depressive symptoms. Therefore, the effect of chronotypes on depressive symptoms can be seen as two parts: a direct effect from chronotypes, and an indirect effect through sleep quality.

The results of the mediating effect test with covariates including sex and age showed that chronotypes had a significant effect on sleep quality (coefficient =  $-0.5159$ , 95%  $CI$ s =  $[-0.7473, -0.2845]$ ,  $P < 0.0001$ ), and sleep quality had a significant effect on depressive symptoms (coefficient =  $0.9473$ , 95%  $CI$ s =  $[0.8864, 1.0082]$ ,  $P < 0.0001$ ), which supported the mediation model proposed in the present study. Moreover, the direct effect of chronotypes on depressive symptoms was found to be not significant (effect =  $-0.1863$ , 95%  $CI$ s =  $[-0.5485, 0.1759]$ ,  $P = 0.3133$ ), while the indirect effect of chronotypes on depressive symptoms (mediated by sleep quality) was significant (effect =  $-0.4887$ ,

**Table 1** Descriptive Statistics and Correlation Analyses

Variable	M	SD	1	2	3	4	5
1 Sex	0.39	0.488	–				
2 Age	20.72	3.554	0.033	–			
3 Chronotypes	3.20	0.494	0.048*	0.006	–		
4 Sleep quality	5.68	2.944	$-0.072^{**}$	$-0.053^{**}$	$-0.09^{**}$	–	
5 Depressive symptoms	5.98	5.351	$-0.056^{**}$	$-0.025$	$-0.065^{**}$	$0.524^{**}$	–

**Notes:** \* $P < 0.05$ , \*\* $P < 0.01$ ; Sex is a dummy variable, male = 1, female = 0, and the mean value indicates the proportion of male; Chronotypes were assessed by Morning and Evening Questionnaire-5, labeled as 1–5 from absolute evening chronotype to absolute morning chronotype; Sleep quality was assessed by Pittsburgh Sleep Quality Index; Depressive symptoms were assessed by Patient Health Questionnaire-9.

**Abbreviations:** M, mean; SD, standard deviation.



Boot  $CI$ s =  $[-0.7389, -0.2684]$ ,  $P < 0.05$ ). Thus, sleep quality fully mediated the correlation between chronotypes and depressive symptoms among the college students surveyed during the COVID-19 pandemic, further suggesting eveningness Chinese college students with poorer sleep quality were more likely to develop higher levels of depressive symptoms.

## Discussion

Contemporary college students live in an era where diverse cultures and values coexist. They encounter problems caused by globalization, network, and urbanization. Furthermore, they have to face pressures accompanying growth, development and choice. Therefore, the mental health problems of college students have become prominent and drawn the attention of researchers worldwide.<sup>54,55</sup> In particular, depressive symptoms and depression have a high prevalence in college students, and are widely concerned.<sup>30,31</sup>

The COVID-19 pandemic, a serious global public health event, has taken a toll on the mental health of college students, resulting in an increase in depressive symptoms/depression among them.<sup>15,18,21</sup> Thus, exploring the factors and mechanisms influencing the development of depressive symptoms and depression among college students during the COVID-19 pandemic is of practical significance to protect college students from depressive symptoms and depression.

The present study found the prevalence of depressive symptoms and sleep disturbances among college students in China during the COVID-19 pandemic was as high as 54.95% and 48.18%, respectively. This was significantly higher than the results of relevant previous studies reported during the non-epidemic period,<sup>31–34</sup> suggesting that the COVID-19 pandemic has adversely affected both mood and sleep among college students. The COVID-19 pandemic, which has posed a threat to human life and has majorly impacted the society and economy,<sup>3,13,16,56</sup> has brought with it a host of adverse factors that may contribute to a higher prevalence of depressive symptoms and sleep disturbances among college students, including various kinds of stress, inability to receive education normally, lockdown restrictions, and social limitations.<sup>17–23,57–59</sup> A recent systematic review published in *The Lancet* reported that the COVID-19 pandemic resulted in an increase of approximately 53 million people (approximately 27.6%) with depression worldwide in 2020.<sup>60</sup> Furthermore, compared with men, women were more likely to be affected by the pandemic and develop depression, and younger age individuals were more affected than older age individuals.<sup>60</sup> Our finding is consistent with this report and further demonstrates that the COVID-19 pandemic increased the prevalence of depressive symptoms among college students. Besides, sleep problem is also a prominent mental health concern among college students caused by the COVID-19 pandemic. In addition to stress, lockdown and other common adverse factors that would also contribute to depressive symptoms, changes in sleep behavior pattern are important factors causing sleep disturbances in college students.<sup>8,10,26–28,61</sup> Moreover, evidences show that problematic internet use, a behaviour found to have increased during the COVID-19 pandemic,<sup>26,62–65</sup> is associated with poor sleep and other mental problems.<sup>66–68</sup> Online activities may distract internet users from psychological distress caused by the COVID-19 pandemic, and social media can offer opportunities to socially connect with others especially in lockdown condition.<sup>64,65,69,70</sup> However, problematic internet use often takes up too much of the users' time and disturbs their sleep-wake behaviors, and real-world problems are generally left to be not solved.<sup>66–69</sup>

The present study found that from absolute evening chronotype to absolute morning chronotype, the surveyed college students' chronotypes were negatively correlated with their depressive symptoms. It indicated that college students with later chronotypes (ie, eveningness) were more likely to develop depressive symptoms and their symptoms would be more severe, which is consistent with several existing studies that have shown the college students' chronotypes to be closely associated with the development of depressive symptoms and depression.<sup>42,61</sup> Evidences suggest that disrupted sleep-wake cycle and melatonin and cortisol secretion may be possible co-factors contributing to the etiology of depressive symptoms in individuals with a late chronotype.<sup>71</sup> Thus, findings of the present study and related studies highlight the importance of reasonable bedtime/circadian preference for college students' emotional regulation. However, delayed bedtime/circadian preference is prominent among college students before and during the COVID-19 pandemic. It has been reported that the prevalence of late sleep was 91.2% among adolescents aged 18–23 years, and that adolescents who slept late had worse sleep quality than those who followed normal bedtime.<sup>72</sup> A study has also shown that approximately 40% of adolescents have delayed sleep which can lead to sleep deprivation and sleep problems such as insomnia.<sup>73</sup> There

may be several reasons for delayed bedtime/circadian preference among college students. In adolescence, the rhythm of melatonin secretion begins to delay with age, and nocturnal melatonin increment declines with physical growth and age.<sup>74</sup> Besides, upon starting college, exogenous factors including multiple roommates, reduced study intensity compared with that in high school, and an increase in internet and electronic device use may contribute to the widespread delayed sleep among college students.<sup>61,66,72,73</sup> As a result, some college students are inclined to develop late chronotypes. Worse still, lifestyle changes and problematic internet use due to the COVID-19 pandemic may further exacerbate this phenomenon.<sup>26–28,56,61–68</sup> Sleep-wake habits of many college students have changed during the COVID-19 pandemic.<sup>26–28,56,61–68</sup> It should be noted that delayed sleep in adolescence may be associated with an increase in incidence and severity of depressive symptoms.<sup>75,76</sup> Moreover, in addition to depression, adolescents with disrupted circadian rhythms may also be at increased risk for other psychiatric disorders.<sup>77</sup> Therefore, attention should be paid to the bedtime/circadian preferences of college students.

The present study further analyzed the mediating mechanism of the correlation between the chronotypes and depressive symptoms of college students and found that sleep quality is a full mediator in this correlation, which calls for more attention to the sleep quality of Chinese college students. Consistently, studies have shown that the sleep quality of college students is closely correlated with their depressive symptoms.<sup>78,79</sup> The result of a meta-analysis on the correlation between sleep quality and depression among Chinese college students demonstrated that the risk of developing depression among college students with poor sleep quality was 2.128 times higher than among those with normal sleep quality.<sup>79</sup> Previous studies have also confirmed that poor sleep quality/insomnia plays an important role in developing depression, with an increase in the risk of new-onset depression by 3 to 8 times in the population.<sup>37,80–82</sup> Therefore, it has been suggested that maintaining good sleep or effective treatment of insomnia is one of the primary preventive measures for depression.<sup>83</sup> In addition, pathogenesis of insomnia may be similar to that of depression.<sup>84</sup> For instance, 5-HT insufficiency can lead to hyperarousal and poor sleep continuity, and also underlie the pathology of depression.<sup>85–87</sup> Besides, hypothalamic-pituitary-adrenal axis dysfunction may be another common pathophysiological alteration of insomnia and depression.<sup>88,89</sup> Thus, it is not difficult to understand the role of sleep quality as a full mediator on the correlation between chronotypes and depressive symptoms among Chinese college students during the COVID-19 pandemic.

However, the previous studies have not clarified whether different chronotypes directly or indirectly increase susceptibility to depressive symptoms among college students. The result of mediating effect analysis in this study demonstrated that during the COVID-19 pandemic, from absolute evening chronotype to absolute morning chronotype, the surveyed college students' depressive symptoms were negatively correlated with their chronotypes through a full mediating effect of their sleep quality (ie, eveningness college students with poorer sleep quality were more likely to report higher levels of depressive symptoms). Therefore, our findings may advance the field of depressive symptoms/depression intervention. For the prevention and treatment of depressive symptoms/depression among college students, promoting reasonable and healthy sleep-wake habits may be a feasible first step, and then improving their sleep quality may be a more important second step.

In summary, the present study further confirmed the high prevalence of depressive symptoms and sleep disturbances among college students in China during the COVID-19 pandemic, and found that sleep quality fully mediated the correlation between chronotypes and depressive symptoms among Chinese college students. Among the surveyed college students, those with eveningness or delayed circadian preference were more likely to develop depressive symptoms and have more severe symptoms than their peers with conventional circadian timing. Among the surveyed college students with the same chronotype, those with good sleep quality were less likely to suffer from depressive symptoms than their peers with poor sleep quality. Good sleep may be the basis for maintaining a good mood. In the future, college educators should pay more attention to college students' sleep behavior patterns, and guide college students to develop a proper chronotype and improve their sleep quality, which may help to reduce the prevalence and severity of depressive symptoms among them.

Despite the important implications, our work has certain limitations. Firstly, the present study was cross-sectional, which makes it difficult to illustrate the causal correlation between chronotypes and depressive symptoms among Chinese college students during the COVID-19 pandemic. Thus, prospective longitudinal studies are warranted to validate the

findings of this study. Secondly, we did not control or measure other possibly relevant factors (eg, substance use other than alcohol and tobacco, and problematic internet use), which could also be mediators influencing the prevalence of depressive symptoms and sleep disturbances and their correlation among Chinese college students during the COVID-19 Pandemic. Last but not least, the use of subjective self-reports would be one limitation of the present study. On the one hand, social desirability is a potential threat to the validity of our findings. On the other hand, the detection rates of depressive symptoms and sleep disturbances may not be as accurate as the results obtained from structured clinical interviews and polysomnography.

## Conclusion

During the COVID-19 pandemic, eveningness Chinese college students with poorer sleep quality were more likely to develop higher levels of depressive symptoms. Sleep quality fully mediated the correlation between chronotypes and depressive symptoms among Chinese college students. Reasonable adjustment in bedtime/circadian preference and improvement in sleep quality may help to reduce the prevalence and severity of depressive symptoms among Chinese college students, although the impact of preventive measures targeting the sleep-wake on mental health in this context worldwide needs further evaluation.

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## Disclosure

All authors report no conflicts of interest in this work.

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