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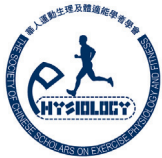
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Movement behaviors and posttraumatic stress disorder during the COVID-19 pandemic: A retrospective study of Chinese university students

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ABSTRACT

Background/objective: This study aimed to examine the associations between physical activity (PA), sedentary behavior, sleep and posttraumatic stress disorder (PTSD) among undergraduate students during the coronavirus disease 2019 (COVID-19) pandemic in China.

Methods: A total of 3178 university students responded to an online questionnaire between December 2020 and January 2021. Participants self-reported the time they spent on PA, screen time and sleep after (over the past seven days) and during the outbreak peak (from January to March 2020). Their sleep quality was measured using the Chinese version of the Pittsburgh Sleep Quality Index. The Chinese version of the Posttraumatic Stress Disorder Checklist - Civilian Version was used to measure PTSD. Logistic regressions and generalized linear mixed models were conducted.

Results: The final analysis included data from 2070 university students (20.2 ± 1.3 years old, 37.0% males). The prevalence of PTSD was 7.1%. Better sleep quality both during and after the outbreak peak, and longer sleep duration after the outbreak peak were associated with a lower odds ratio of having PTSD and lower re-experiencing, avoidance and hyperarousal scores. Higher total PA levels during the outbreak peak were associated with a higher odds ratio of having PTSD and higher levels of re-experiencing and avoidance.

Conclusion: Sleep quality and duration were negatively associated with PTSD among university students during the COVID-19 pandemic. The associations between PA, screen time and PTSD require further examination. Future interventions to enhance mental health could consider targeting university students' sleep hygiene.

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1. Introduction

Widespread outbreaks of the coronavirus disease 2019 (COVID-19) pandemic have adversely affected people's mental health. A recent systematic review found a relatively high prevalence of symptoms of anxiety (6.3%–50.9%), depression (14.6%–48.3%), stress (8.1%–81.9%) and posttraumatic stress disorder (PTSD; 7.0%–53.8%) among the general population during the COVID-19

pandemic¹; while another review conducted before the pandemic outbreak found that the prevalence of PTSD ranged from 1.3% to 8.8% across countries.² Although depressive symptoms may vanish quickly, PTSD may last for a long time after the pandemic.³ Following infectious disease pandemics such as Sudden Acute Respiratory Syndrome (SARS) and COVID-19, the overall prevalence of PTSD exceeded one fifth⁴; even three years after the SARS pandemic, one in ten hospital employees experienced PTSD symptoms.⁵ PTSD is a common psychiatric disorder that occurs in individuals who have been exposed to a traumatic event. Its core characteristics include repeatedly re-experiencing the trauma, trying to avoid events related to the trauma experience, hyperarousal, negative cognitive and emotional states, sleep difficulties

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and other symptoms.⁶ Individuals diagnosed with PTSD are more likely to have secondary disorders and to experience marital instability and academic failure, thus placing a heavy burden on their families and societies.⁷

Compared with the general population, university students experienced higher rates of mental health disorders in the pre-pandemic situation.⁸ The university years mean transferring from late adolescence to adulthood, and students of this age may experience some stress for the first time (e.g., work and family responsibilities) in addition to academic performance, making this period full of unprecedented independence and uncertainty.⁹ Concurrently, their brain were in a period of rapid development and high sensitivity to negative environmental factors,¹⁰ and many of them had first onset of mental health problems.¹¹ According to a large-scale survey in the United States, more than a quarter of university students self-reported having mental health diagnoses in the past 12 months and one fifth of them have ever had suicidal ideation (from birth to the day they were surveyed).¹² A systematic review reported that the average prevalence of PTSD among university students during the COVID-19 pandemic was as high as 30%.¹³ However, to the best of our knowledge, studies on PTSD during the COVID-19 pandemic were rarely conducted among university students in China.^{14,15}

Movement behaviors, including physical activity (PA), sedentary behavior and sleep, are associated with mental health. For instance, sleep problems such as insomnia have been found to predict depression,¹⁶ while shorter sleep duration and lower sleep quality have been associated with higher levels of PTSD among adults.^{14,17} A systematic review found that individuals with PTSD had lower levels of PA,¹⁸ whereas improving PA was effective at reducing PTSD symptoms.¹⁹ As for sedentary behavior, a longer time spent sitting has been associated with higher levels of PTSD.¹⁷ After the COVID-19 pandemic outbreak, studies found that university students' levels of PA declined,²⁰ whereas their sedentary behavior and sleep duration increased.^{20,21} However, the correlations between these movement behaviors and PTSD among university students during the COVID-19 pandemic remain unknown; most studies have focused on influencing factors such as socio-demographic information and exposures to the pandemic.^{14,22} In addition, measurements at different stages of the pandemic (e.g., during and after the outbreak peak) are needed to elucidate the longitudinal relationships between movement behaviors and PTSD. This retrospective study therefore explored the associations between movement behaviors during and after the outbreak peak and PTSD among university students. We hypothesized that higher levels of PA, less screen time (ST), longer sleep duration, and higher sleep quality both during (Time 0) and after the outbreak peak (Time 1) were associated with lower risks of having PTSD and lower levels of re-experiencing, avoidance, and hyperarousal (Time 1).

2. Methods

2.1. Participants

The retrospective study was conducted in Guangdong province, China, using convenience sampling. The inclusion criteria were (1) being an undergraduate student and (2) being physically and mentally healthy. The online questionnaire was developed using the Wenjuanxing platform (<https://www.wjx.cn/>). The link and a QR code were distributed by staff and student helpers in one university, and all students were encouraged to participate in this survey. There were no incentives for completing the survey. A total of 3178 students submitted their answers during the data collection period from December 4, 2020 to January 4, 2021, and each respondent signed a consent form. This study was approved by the

Research Ethics Committee, Beijing Normal University & Hong Kong Baptist University United International College (Ref. No.: REC-2021-07).

Students were asked to report and recall their exposures to COVID-19, PTSD symptoms, and demographic information. Movement behaviors during two periods were reported: present (i.e., after the outbreak peak, Time 1) and during the outbreak peak (i.e., from January to March 2020, Time 0). According to the Oxford COVID-19 Government Response Tracker (OxCGRT),²³ the outbreak peak of the COVID-19 pandemic in China was defined as taking place from January to March 2020 (Time 0). Most provinces experienced the peak of the first COVID-19 wave during Time 0, the number of new confirmed cases ranged from dozen to tens of thousands per day, and even reached 30,000 per week in February 2020.²⁴ During this time, stringent precautionary measures were implemented in Mainland China, such as school closures and stay-at-home requirements.²³ Starting from May 2020, the development of the pandemic in China has slowed and stabilized, with less than 100 new confirmed cases per day on most days.²⁴ Therefore, the survey period from December 2020 to January 2021 (Time 1) was considered “after the outbreak peak” when universities had reopened and students' daily schedules had returned to normal.

2.2. Exposures to the COVID-19 pandemic

Exposures to the COVID-19 pandemic was measured by the COVID-19 exposure scale.¹⁴ Students were asked to recall their experiences and feelings since the outbreak of the pandemic and to respond ‘yes’ or ‘no’ to each of nine statements: (1) people infected in their community; (2) lived in the worst-hit areas; (3) knew someone who died of the infection; (4) neighbors infected; (5) friends infected; (6) relatives infected; (7) exposed to stressful mass media information; (8) family members infected and (9) felt extreme fear of being infected. The score of COVID-19 exposure (ranging from 0 to 9) was calculated as the sum of ‘yes’ responses.¹⁴

2.3. Movement behaviors after the outbreak peak (time 1)

PA during the past seven days was measured using the Chinese version of the International Physical Activity Questionnaire - Short Form (IPAQ-SF).²⁵ Activities included walking, moderate-intensity PA (MPA) and vigorous-intensity PA (VPA). Total PA (metabolic equivalent of task; MET-hours/day) was defined as the total energy expenditure of walking (3.3 METs), MPA (4.0 METs) and VPA (8.0 METs). Data of PA were screened following screening criteria for IPAQ.²⁶ ST was measured using one question: ‘Over the past seven days, how much time on average did you spend on ST (e.g., watching TV, using computers/tablets/mobile phones) per day?’ ST were considered invalid if it was reported more than 12 h.²⁷

The Chinese version of the Pittsburgh Sleep Quality Index (PSQI)²⁸ was used to assess sleep-related outcomes over the past one month. Students reported their actual sleep duration, bedtime, wakeup time the subsequent day and the duration from bedtime to falling asleep (sleep latency). Sleep efficiency was measured as actual sleep duration divided by time in bed (wake up time the subsequent day – bedtime). One question was asked to measure sleep quality: ‘Over the past month, how would you rate your sleep quality?’ Four options from ‘0, very good’ to ‘3, very bad’ were provided. Unreasonable responses were considered invalid and excluded in the final analysis (e.g., sleep duration was shorter than 1 h or longer than 20 h, actual sleep duration was longer than time in bed).²⁹

2.4. Movement behaviors during the outbreak peak (time 0)

To measure movement behaviors during the outbreak peak, students responded to the following questions: ‘During the outbreak peak of the COVID-19 pandemic (from January to March 2020), how much time on average did you spend on (1) all PA intensities (e.g., walking, running, playing ball, doing housework); (2) ST (e.g., watching TV, using computers/tablets/mobile phones); (3) actual sleep duration per day?’ To assess sleep quality, the same question as above was used, based on the PSQI.²⁸ The same criteria of screening movement behaviors after the outbreak peak were also applied.^{26,27,29}

2.5. Post-traumatic stress disorder (PTSD)

PTSD was measured by the Chinese version of the Posttraumatic Stress Disorder Checklist - Civilian Version (PCL-C).³⁰ The PCL-C consisted of 17 items, covering three components: re-experiencing (five items), avoidance (seven items) and hyperarousal (five items). Five options ranging from ‘1, not at all’ to ‘5, extremely’ were provided for each item, with a higher score indicating a more severe symptom. Responses from ‘3, moderately’ to ‘5, extremely’ were defined as symptomatic for each item. If a respondent was symptomatic for at least one re-experiencing item, three avoidance items and two hyperarousal items, they were defined as having PTSD.^{30,31} These criteria have commonly been applied among Chinese adults.³⁰

2.6. Demographic information

Students’ information including age, sex, height, weight and where they were living during the outbreak peak were collected using self-reported questions. Body mass index (BMI; kg/m²) was calculated based on height and weight.

2.7. Statistical analyses

The mean and standard deviation were provided for continuous variables and the number of participants and percentages were used to present categorical variables. Logistic regressions were conducted to explore the associations between potential predictors (movement behaviors during and after the outbreak peak) and risk of having PTSD. To predict three components of PTSD (re-experiencing, avoidance, and hyperarousal), generalized linear mixed models with Gamma distribution were applied, with movement behaviors during and after the outbreak peak used as the predictors. Two models were run for each regression. Model 1 adjusted for age, sex, BMI, and COVID-19 exposure score, with one movement behavior included as the predictor; Model 2 adjusted all covariates in Model 1, with all movement behaviors included. There was no multicollinearity among the predictors in the Model 2.³² SPSS 26 software (IBM, Armonk, New York) was used to conduct all statistical analyses. The significance level was set at $p < 0.05$.

3. Results

A total of 3178 responses were received. After data cleaning, 2070 students (20.2 ± 1.3 years old, 37.0% male) provided complete and valid data and were included in the final data analysis. No differences were found between the included and excluded participants in demographic factors, except that the BMI of the included students was lower than that of the excluded students (21.9 ± 5.0 vs. 22.3 ± 5.7, $p < 0.05$). Among the included sample, 43.9% of the participants were living in Guangdong province during the outbreak peak, and the others’ residential areas covered almost

all provinces, municipalities, and autonomous regions in China. Based on a power of 0.80, a p value of 0.05 and 11 predictors in a regression model, this sample size can detect an effect size f^2 of less than 0.01. The characteristics and movement behaviors of the participants are presented in Table 1. Overall, 7.1% of the students were diagnosed as having PTSD.

For COVID-19 exposures, 29.5% of the students reported that they felt extreme fear of being infected, 7.3% were exposed to stressful mass media information, 5.3% experienced people being infected in their community and fewer than 5.0% had other COVID-19 exposures.

Self-reported total PA was 6.9 ± 5.2 MET-hours/day at Time 1, and 1.0 ± 1.1 h/day during the outbreak peak (Time 0). The differences in time spent in ST and sleep between Time 1 and Time 0 were as follows: ST (5.7 ± 2.7 vs. 6.4 ± 2.9 h/day, $p < 0.01$) and

Table 1
Participants’ characteristics and movement behaviors (n = 2070).

	Mean ± SD or n (%)
Demographics	
Age (year)	20.2 ± 1.3
Sex (male)	766 (37.0%)
BMI (kg/m ²)	21.9 ± 5.0
Exposure to COVID-19 (yes)	
People infected in their community	109 (5.3%)
Lived in the worst-hit areas	62 (3.0%)
Knew someone who died of the infection	40 (1.9%)
Neighbors infected	41 (2.0%)
Friends infected	42 (2.0%)
Relatives infected	34 (1.6%)
Exposed to stressful mass media information	151 (7.3%)
Family members infected	31 (1.5%)
Felt extreme fear of being infected	610 (29.5%)
Exposure to COVID-19 score	0.54 ± 1.23
Movement behaviors after the outbreak peak^a	
Total physical activity MET-h/day	6.9 ± 5.2
Screen time (h/day)	5.7 ± 2.7
Sleep duration (h/day)	6.9 ± 1.2
Sleep efficiency (%)	87.3 ± 12.5
Sleep latency (min/day)	19.8 ± 22.6
Sleep quality	
Very good	685 (33.1%)
Fairly good	1040 (50.2%)
Fairly bad	312 (15.1%)
Very bad	33 (1.6%)
Movement behaviors during the outbreak peak^b	
Total physical activity (h/day)	1.0 ± 1.1
Screen time (h/day)	6.4 ± 2.9
Sleep duration (h/day)	7.4 ± 1.9
Sleep quality	
Very good	1047 (50.6%)
Fairly good	808 (39.0%)
Fairly bad	193 (9.3%)
Very bad	22 (1.1%)
Post-traumatic stress disorder^c	
Re-experiencing (score)	7.0 ± 3.2
Avoidance (score)	9.6 ± 4.3
Hyperarousal (score)	7.1 ± 3.2
Having post-traumatic stress disorder	147 (7.1%)

Abbreviations: BMI, body mass index; COVID-19, coronavirus disease 2019; MET: metabolic equivalent of task.

^a Measured by the International Physical Activity Questionnaire-Short Form (IPAQ; 7-day recall) between December 2020 and January 2021; total physical activity includes walking, moderate physical activity, and vigorous physical activity.

^b Retrospective recall between January and March 2020, total physical activity was measured by one question, including all intensities of physical activity.

^c Range of the subscale score: re-experiencing, 5.0–25.0; avoidance, 7.0–35.0; hyperarousal, 5.0–25.0. Having PTSD was defined as being symptomatic of at least one item on re-experiencing, three items on avoidance, and two items on hyperarousal.

sleep duration (6.9 ± 1.2 vs. 7.4 ± 1.9 h/day, $p < 0.01$). For sleep quality, 33.1% and 50.6% of the students rated their sleep quality as very good after and during the outbreak peak, respectively.

The associations between potential predictors and the risk of having PTSD are shown in Table 2. Having a longer sleep duration after the outbreak peak was associated with a lower risk of having PTSD (odds ratio [OR] = 0.78; 95% confidence interval [CI]: 0.65, 0.94). Worse sleep quality both after (OR = 1.60; 95% CI: 1.21, 2.11) and during the outbreak peak (OR = 2.29; 95% CI: 1.76, 2.99) was associated with a higher OR of being diagnosed with PTSD. However, having more PA during the outbreak peak (OR = 1.27; 95% CI: 1.11, 1.45) was also associated with a higher risk of having PTSD.

The associations between movement behaviors and the three components of PTSD are presented in Table 3. Having better sleep quality during and after the outbreak peak and having a longer sleep duration after the outbreak peak were associated with lower re-experiencing, avoidance and hyperarousal scores. Higher PA during the outbreak peak was associated with higher scores of re-experiencing and avoidance.

4. Discussion

To the best of our knowledge, this is the first study to examine the associations between movement behaviors during and after the outbreak peak of the COVID-19 pandemic and PTSD among Chinese university students. We found that higher sleep quality during and after the outbreak peak and a longer sleep duration after the outbreak peak were associated with a lower risk of having PTSD, as well as lower levels of re-experiencing, avoidance and hyperarousal. Individuals with higher total PA during the outbreak peak were more likely to be diagnosed as having PTSD and have higher levels of re-experiencing and avoidance approximately 10–12 months later.

The prevalence of PTSD (7.1%) observed in this study was higher than that reported in February 2020 among university students in China (2.7%),¹⁴ but lower than another study conducted in April 2020 (16.3%).¹⁵ This variation could be explained by different durations of exposure to the pandemic: a longer duration of exposure to traumatic stressors was associated with increased PTSD symptoms.³³ In the developing stage of the COVID-19 pandemic, therefore, people's mental health became worse. During the data collection period of this study, however, control of the pandemic had almost been achieved in Mainland China; people's PTSD symptoms may thus have been ameliorated. In addition, it's worth noting that sampling methodology, characteristics of participants

(e.g., sex ratio), measurements of PTSD used, and the residential areas of participants during the pandemic may contribute to the discrepancy between studies.

The findings that both sleep quality and duration were associated with PTSD were consistent with our hypothesis. A cohort study conducted among Chinese adolescents found that those who had worse sleep quality 12 months after an earthquake were more likely to have PTSD at both 12 months and 24 months after the earthquake.³⁴ Similar to sleep quality, longer sleep duration after the outbreak peak was associated with a lower OR of having PTSD and lower levels of re-experiencing, avoidance and hyperarousal. These findings are supported by existing evidence. Goodwin et al. found that short sleep duration was associated with a high likelihood of having PTSD.³⁵ The relationship between sleep duration and PTSD also existed during the COVID-19 pandemic: a study conducted among Chinese university students found that longer sleep duration was associated with lower PTSD scores.¹⁴ It is worth noting that the relationship between sleep and mental health may be bi-directional.^{16,36} Nevertheless, our finding further demonstrated that sleep during the peak of the pandemic outbreak was still associated with PTSD among university students 9–12 months later when their daily routines had mostly returned to normal. Considering the importance of sleep, future interventions targeting sleep hygiene are needed to improve university students' mental health after exposure to a traumatic event.

Contrary to our hypothesis, higher total levels of PA during the outbreak peak were associated with a higher risk of having PTSD and higher levels of re-experiencing and avoidance. Existing evidence regarding the relationship between PA and PTSD is mixed. For example, a previous study conducted in South Africa among people older than 15 years found that higher PA levels were associated with higher total PTSD scores, as well as higher levels of re-experiencing and avoidance.³⁷ However, LeardMann et al. found that healthy adults with higher levels of PA were less likely to have PTSD.³⁸ Moreover, Mason et al. reported no association between PA and PTSD.¹⁷ These disparate responses were unexpected but should not be surprising. According to Seigel et al., individuals showed different behavioral responses (increased PA, decreased PA, no change) to stress.³⁹ In a systematic review, the majority of the included studies found that higher levels of stress were associated with decreased PA and one fifth of studies reported a positive relationship between stress and PA.⁴⁰ However, based on the nature of the correlations examined in this study, we may expect that students with higher levels of PA were more likely to have PTSD, or that students with more PTSD symptoms were more physically

Table 2
Associations between movement behaviors and risk of having post-traumatic stress disorder.

	OR (95% CI)	
	Model 1	Model 2
Movement behaviors after the outbreak peak		
Total physical activity MET-h/day	0.99 (0.96, 1.02)	1.00 (0.97, 1.04)
Screen time (h/day)	1.01 (0.95, 1.08)	1.03 (0.95, 1.11)
Sleep duration (h/day)	0.72 (0.64, 0.81)**	0.78 (0.65, 0.94)*
Sleep quality ^a	2.65 (2.12, 3.31)**	1.60 (1.21, 2.11)**
Sleep efficiency (%)	0.07 (0.02, 0.20)**	0.61 (0.12, 3.14)
Sleep latency (min/day)	1.01 (1.01, 1.02)**	1.01 (1.00, 1.01)
Movement behaviors during the outbreak peak		
Total physical activity (h/day)	1.18 (1.04, 1.34)*	1.27 (1.11, 1.45)**
Screen time (h/day)	0.99 (0.94, 1.05)	0.95 (0.88, 1.02)
Sleep duration (h/day)	0.94 (0.87, 1.02)	1.06 (0.95, 1.17)
Sleep quality ^a	2.93 (2.36, 3.65)**	2.29 (1.76, 2.99)**

Abbreviations: OR, odds ratio; 95% CI, 95% confidence interval; MET: metabolic equivalent of task.

Model 1: adjusted for age, sex, body mass index (BMI), and exposure to coronavirus disease 2019 (COVID-19) score.

Model 2: included all movement behaviors and all covariates in Model 1.

** $p < 0.01$, * $p < 0.05$.

^a a higher score indicates worse sleep quality.

Table 3
Associations between university exposures to COVID-19, movement behaviors and the three dimensions of post-traumatic stress disorder (continuous variables).

	B (95% CI)					
	Re-experiencing		Avoidance		Hyperarousal	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Movement behaviors after the outbreak peak						
Total physical activity MET-h/day	0.00 (−0.00, 0.00)	0.00 (−0.00, 0.01)	−0.00 (−0.01, 0.00)	−0.00 (−0.00, 0.00)	−0.00 (−0.01, 0.00)	0.00 (−0.00, 0.00)
Screen time (h/day)	0.00 (−0.01, 0.01)	−0.00 (−0.01, 0.00)	0.00 (−0.00, 0.01)	−0.00 (−0.01, 0.00)	0.01 (0.00, 0.01)*	0.00 (−0.01, 0.01)
Sleep duration (h/day)	−0.05 (−0.06, −0.03)**	−0.02 (−0.04, −0.01)**	−0.05 (−0.07, −0.04)**	−0.03 (−0.05, −0.01)**	−0.06 (−0.07, −0.05)**	−0.03 (−0.04, −0.01)**
Sleep quality ^a	0.17 (0.14, 0.19)**	0.09 (0.06, 0.12)**	0.18 (0.16, 0.20)**	0.11 (0.08, 0.13)**	0.23 (0.21, 0.25)**	0.13 (0.10, 0.15)**
Sleep efficiency (%)	−0.42 (−0.55, −0.28)**	−0.10 (−0.26, 0.06)	−0.41 (−0.54, −0.28)**	−0.06 (−0.21, 0.10)	−0.48 (−0.62, −0.35)**	−0.09 (−0.24, 0.06)
Sleep latency (min/day)	0.00 (0.00, 0.00)**	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)**	0.00 (0.00, 0.00)	0.00 (0.00, 0.01)**	0.00 (0.00, 0.00)
Movement behaviors during the outbreak peak						
Total physical activity (h/day)	0.01 (−0.00, 0.03)	0.02 (0.01, 0.04)**	0.01 (−0.01, 0.02)	0.02 (0.00, 0.03)*	−0.01 (−0.02, 0.01)	0.01 (−0.01, 0.02)
Screen time (h/day)	0.00 (−0.00, 0.01)	0.00 (−0.01, 0.01)	0.01 (0.00, 0.01)*	0.01 (−0.00, 0.01)	0.01 (0.00, 0.01)*	0.00 (−0.01, 0.01)
Sleep duration (h/day)	−0.01 (−0.02, 0.00)	0.01 (−0.00, 0.02)	−0.01 (−0.01, 0.00)	0.00 (−0.01, 0.01)	−0.01 (−0.01, 0.00)	0.01 (0.00, 0.02)
Sleep quality ^a	0.19 (0.17, 0.21)**	0.13 (0.11, 0.16)**	0.19 (0.17, 0.21)**	0.12 (0.10, 0.15)**	0.24 (0.22, 0.27)**	0.16 (0.14, 0.19)**

Abbreviations: 95% CI, 95% confidence interval; MET: metabolic equivalent of task.
Model 1: adjusted for age, sex, body mass index (BMI), and exposure to coronavirus disease 2019 (COVID-19) score.
Model 2: included all movement behaviors and all covariates in Model 1.

**p < 0.01, *p < 0.05.

^a a higher score indicates worse sleep quality.

active: that is, they increased their PA as a compensation.

The associations between ST both during and after the outbreak peak and the risk of PTSD were not observed when other movement behaviors and covariates were adjusted in the models, although longer ST during the outbreak peak was associated with higher levels of avoidance and hyperarousal in the crude models. These findings echo previous systematic reviews, which found that longer ST were associated with a range of mental health problems, such as depression and anxiety.^{41,42} The crude measurement of ST in this study may have been one of the reasons for this unexpected finding. Considering the difficulty of recalling one's behaviors over a long period of time, only one question was used for reporting ST. Subjective measurements and recall bias made it difficult to determine the associations between ST and PTSD. It is also worth noting that ST during the outbreak peak was as high as 6.4 h per day among university students in this study. A previous study found that young adults increased their ST for the purpose of connecting with others after the outbreak of the COVID-19 pandemic.⁴³ Social connectedness has been a crucial coping strategy during the pandemic among university students, so longer ST may not necessarily be negatively associated with mental health.⁴⁴ However, the specific contents of ST were not specified in our measurement. Future studies are warranted to explore whether the associations between sedentary time and PTSD, if any, are mediated by the content or purpose of the sedentary activity.

This study recruited a relatively large sample size, used reliable and valid measurements and measured movement behaviors during and after the outbreak peak. The study also had some limitations. First, a retrospective design was applied and no causality can be determined. Second, there may have been a recall bias given that participants were asked to recall their movement behaviors during the outbreak peak, although this measurement has commonly been used to collect information on movement behaviors retrospectively during the COVID-19 pandemic.^{45,46} Third, similar to previous studies during the pandemic, more female university students responded to the survey.^{47,48} Due to the specificity of the population group and sampling bias using convenience sampling, our findings could not be generalized to the general public. Lastly, using PCL-C may not have been sufficient for a clinical diagnosis of PTSD, although PCL-C was generally accepted as a screening tool and the

criteria used in this study have been commonly used among Chinese adults.

5. Conclusions

University students who had better sleep quality during and after the outbreak peak were less likely to have PTSD. Those who slept longer after the outbreak peak also had a lower risk of having PTSD. More studies are needed to explore the relationship between PA, ST and PTSD among university students. Future interventions aimed at improving mental health problems should focus on sleep hygiene and improving both sleep duration and sleep quality.

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Author contributions

Jie Feng: Methodology, Investigation, Writing - original draft; Patrick Wing Chung Lau and Lei Shi: Investigation, Writing - review & editing; Wendy Yajun Huang: Conceptualization, Methodology, Investigation, Writing - review & editing.

Declarations of interest

None.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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