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Association of Symptoms of Attention Deficit and Hyperactivity with Problematic Internet Use among University Students in Wuhan, China During the COVID-19 Pandemic

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ABSTRACT

Background: COVID-19 is still spreading worldwide and posing a threat to individuals' physical and mental health including problematic internet use (PIU). A potentially high-risk group for PIU are those with symptoms of attention deficit and hyperactivity (ADHD symptoms), because of restrictions in their physical activity levels and engagement in computer diversions requiring only short attention spans.

Methods: We used convenience sampling in a cross-sectional survey of university students from 30 universities in Wuhan, Hubei Province, China. We assessed PIU using the Internet Addiction Test and ADHD symptoms using the WHO Adult ADHD Self-Report Screening Scale. Using logistic regression and linear regression analyses we adjusted for demographic, epidemic-related and psychological covariates in models of the association between ADHD symptoms and PIU.

Results: Among 11,254 participants, we found a 28.4% (95% CI, 27.5%-29.2%) prevalence of PIU, relatively higher than before the pandemic. In our final logistic regression model, participants with ADHD symptoms had approximately two times the risk for PIU (OR: 2.31, 95% CI: 1.89-2.83). Similarly, individuals with depression, anxiety, insomnia, PTSD symptoms and feeling stress during the pandemic had a higher risk of PIU, while those exercising regularly during the pandemic had a lower risk.

Limitations: The cross-sectional design and reliance on internet based self-reports for ADHD symptoms and PIU assessments, without direct structured interviews for validation, are limitations.

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Conclusions: The prevalence of PIU was high during COVID-19, and those people with ADHD symptoms and other mental illness symptoms appear to be at higher risk of PIU. Regular exercise may reduce that PIU risk and hence should be recommended during the COVID-19 pandemic.

1. Introduction

Up to now, coronavirus disease 2019 (COVID-19), initially detected in December, 2019, has been in control in some countries, whereas in other many countries and regions the pandemic still prolongs and represents a great threat to individuals' as well as societal physical and mental health (Bao et al., 2020). During the outbreak period, "spatial distancing", which is strongly promoted to curb the spread, has disrupted many normal personal interactions (Abel and McQueen, 2020; Liu et al., 2020; Sun et al., 2020a). The resulting regulations have profoundly influenced people from all walks of life, including university students. Several studies found that the prevalence of problematic internet use (PIU) or problematic smartphone use or internet addiction for children, adolescents and young adults in countries and regions affected by COVID-19 has mounted substantially (Deslandes and Coutinho, 2020; Dong et al., 2020; Elhai et al., 2020; Rolland et al., 2020; Sun et al., 2020b).

With the temporary closure of universities, the total online time of university students has gone up considerably for studying online and socializing, which may make them more susceptible to PIU. Academic stress, high levels of uncertainty regarding the future, the pressure of job hunting for graduates, confirmed/suspected COVID-19, or close contacting with patients, experiencing quarantine and other series of factors induced by the pandemic could make university students be under unprecedented pressure and be more likely to experience severe psychological distress and mental problems (Király et al., 2020). Experiencing quarantine and other stressors associated with the pandemic can also trigger addictive activities including PIU as ways to alleviate stress, anxiety, depression, and even post-traumatic stress disorder (PTSD) (Blasi et al., 2019; Khantzian, 2013; Király et al., 2020; Wang et al., 2021).

A common comorbidity of PIU is attention deficit hyperactivity disorder (ADHD) (Carli et al., 2013; Tatenó et al., 2018; Tatenó et al., 2016). It is possible that this association between ADHD and PIU might strengthen during the COVID-19 pandemic. However, to our knowledge, no study has yet investigated the association between ADHD and PIU during the COVID-19 pandemic. Therefore, on the one hand, we want to explore how the association between ADHD and PIU may be influenced by the epidemic-related and other factors. On the other hand, the prevalence of PIU in the previous studies was mostly obtained in the early outbreak stage when people were in a so-called emotional response spike at a time of facing high risk of infection virus as well as uncertainty for future, so we want to know the prevalence of PIU among university students after a long-term quarantine. For the above purposes, we conducted a cross-sectional study after long-term school closure among university students. In this period, the COVID-19 pandemic was largely under control in China except for a small-scale outbreak in several regions occasionally, and meanwhile university students have stayed at home for more than half a year and still didn't return to campus.

2. Methods

2.1. Study design and participants

We conducted a cross-sectional online study from June 29, 2020, to July 18, 2020 among university students from 30 universities in Wuhan, Hubei Province, China, by convenience sampling method. With the help of the class instructor, our self-administered questionnaire was released to the class Wechat group, to which university students pay attention routinely. The investigation was anonymous with confidentiality

assured for all information. This study received the approval from the ethics committee of Peking University Sixth Hospital (Institute of Mental Health) and followed the American Association for Public Opinion Research reporting guidelines. Informed consent was received online before the respondents began the questionnaire.

A total of 65,845 students clicked on the survey link, of whom 11,325 individuals provided the informed consent, resulting in a participation rate of 17.2%. The participants came from 31 province-level regions in China and attended 30 universities in Wuhan, Hubei Province. 71 individuals were excluded because of invalid questionnaires indicated by extreme, out of range values and inconsistent responses to the same questions in different parts of the questionnaire. Thus, we included 11,254 individuals in the final analysis.

2.2. Measurements and covariates

2.2.1. Problematic internet use (PIU)

We measured participants' PIU using the Internet Addiction Test (IAT), which includes 20 items with a total score from 20 to 100. IAT scores between 20 and 49 reflect average online users, while scores between 50 and 79 reflect problem users and scores between 80 and 100 indicate significant internet use problems (Aboujaoude, 2010). In this study, we applied a cutoff for the PIU of a score of 50 or more.

2.2.2. Symptoms of attention deficit and hyperactivity (ADHD symptoms)

We measured participants' ADHD symptoms using the WHO Adult ADHD Self-Report Screening Scale (ASRS-V1.1), which consists of 6 items using a 5-point Likert scale: 1, not at all; 2, rarely; 3, sometimes; 4, often; 5, always. Respondents who endorsed at least four out of six items were considered at "elevated" risk for Adult ADHD. (Kessler et al., 2005).

2.2.3. Covariates

As listed in Table 1, we collected nine demographics including gender, age, and nationality. We collected nine epidemic-related variables as also listed in Table 1. Table 1 also lists four psychological variables measured by the Patient Health Questionnaire-9 (PHQ-9) (Sun et al., 2017), Generalized Anxiety Disorder-7 (GAD-7) (Qu and Sheng, 2015), Insomnia Severity Index (ISI) (Morin et al., 2011), and PTSD checklist for DSM-5 (PCL-5) (Wang et al., 2015). The total scores of these scales were interpreted as follows: PHQ-9, normal (0-4), mild (5-9), moderate to severe (10-27) depression symptoms; GAD-7, normal (0-4), mild (5-9), moderate to severe (10-21) anxiety symptoms; ISI, normal (0-7), subthreshold (8-14), moderate to severe (15-28) insomnia symptoms. The cutoff for positive PTSD symptoms was a score of 33 or more.

2.3. Statistical analysis

We used χ^2 tests to compare the prevalence of PIU in different categorical variables and logistic regression analysis for the association of ADHD symptoms with PIU. We presented the adjusted odds ratio and 95% confidential intervals (95% CIs) of ADHD symptoms for PIU populations. We adjusted for different covariates in three models. Model 1 adjusted for demographic characteristics, including gender, age, education level, graduation, and monthly family income. Model 2 adjusted for epidemic-related factors in addition to the covariates in model 1. Model 3 adjusted for psychological factors in addition to the covariates in model 2. We also conducted linear regression analyses to investigate the relationship of ADHD symptoms, other mental illness symptoms and PIU, with regarding PIU, ADHD, depression, anxiety, insomnia, and

Table 1
Demographic Characteristics, Epidemic-related Information and Psychological Factors by Problematic Internet Use Subgroups.

| | No. (%) | | | p value ^a |
|--|-----------------|--------------|------------------|----------------------|
| | Total (n=11254) | PIU (n=3191) | Non-PIU (n=8063) | |
| Gender | | | | |
| Male | 4054 (36.0%) | 1251 (30.9%) | 2803 (69.1%) | <0.001 |
| Female | 7200 (64.0%) | 1940 (26.9%) | 5260 (73.1%) | |
| Age, y | | | | 0.048 |
| 15-20 | 8139 (72.3%) | 2350 (28.9%) | 5789 (71.1%) | |
| >20 | 3115 (27.7%) | 841 (27.0%) | 2274 (73.0%) | |
| Living area during the COVID-19 pandemic | | | | <0.001 |
| Hubei Province | 6960 (61.8%) | 1890 (27.2%) | 5070 (72.8%) | |
| Other provinces | 4294 (38.2%) | 1301 (30.3%) | 2993 (69.7%) | |
| Nation | | | | 0.237 |
| Han nationality | 10421 (92.6%) | 2940 (28.2%) | 7481 (71.8%) | |
| National minority | 833 (7.4%) | 251 (30.1%) | 582 (69.9%) | |
| Education level | | | | <0.001 |
| College or higher | 8045 (71.5%) | 2448 (30.4%) | 5597 (69.6%) | |
| Less than college | 3209 (28.5%) | 743 (23.2%) | 2466 (76.8%) | |
| Major | | | | 0.71 |
| Medicine | 824 (7.3%) | 229 (27.8%) | 595 (72.2%) | |
| Non-medicine | 10430 (92.7%) | 2962 (28.4%) | 7468 (71.6%) | |
| Graduation | | | | <0.001 |
| Yes | 408 (3.6%) | 153 (37.5%) | 255 (62.5%) | |
| No | 10846 (96.4%) | 3038 (28.0%) | 7808 (72.0%) | |
| Singlehood | | | | 0.53 |
| Yes | 9025 (80.2%) | 2547 (28.2%) | 6478 (71.8%) | |
| No | 2229 (19.8%) | 644 (28.9%) | 1585 (71.1%) | |
| Monthly family income, ¥ | | | | <0.001 |
| ≤10,000 | 9290 (82.5%) | 2593 (27.9%) | 6697 (72.1%) | |
| >10,000 | 1964 (17.5%) | 598 (30.4%) | 1366 (69.6%) | |
| Only child | | | | 0.202 |
| Yes | 4995 (44.4%) | 1386 (27.7%) | 3609 (72.3%) | |
| No | 6259 (55.6%) | 1805 (28.8%) | 4454 (71.2%) | |
| Experiencing quarantine | | | | <0.001 |
| Yes | 5215 (46.3%) | 1564 (30.0%) | 3651 (70.0%) | |
| No | 6039 (53.7%) | 1627 (26.9%) | 4412 (73.1%) | |
| Living alone during the COVID-19 pandemic | | | | 0.58 |
| Yes | 82 (0.7%) | 21 (25.6%) | 61 (74.4%) | |
| No | 11172 (99.3%) | 3170 (28.4%) | 8002 (71.6%) | |
| Confirmed/suspected COVID-19 or close contacting with patients | | | | <0.001 |
| Yes | 76 (0.7%) | 42 (55.3%) | 34 (44.7%) | |
| No | 11178 (99.3%) | 3149 (28.2%) | 8029 (71.8%) | |
| Family members who are confirmed/suspected COVID-19 or close contacting with patients | | | | <0.001 |
| Yes | 80 (0.7%) | 37 (46.3%) | 43 (53.8%) | |
| No | 11174 (99.3%) | 3154 (28.2%) | 8020 (71.8%) | |
| Acquiring some psychological knowledge during the COVID-19 pandemic | | | | 0.001 |
| Yes | 6746 (59.9%) | 1832 (27.2%) | 4914 (72.8%) | |
| No | 4508 (40.1%) | 1359 (30.1%) | 3149 (69.9%) | |
| Receiving psychological interventions during the COVID-19 pandemic | | | | <0.001 |
| Yes | 513 (4.6%) | 194 (37.8%) | 319 (62.2%) | |
| No | 10741 (95.4%) | 2997 (27.9%) | 7744 (72.1%) | |
| Exercising during the COVID-19 pandemic | | | | <0.001 |
| Yes | 4686 (41.7%) | 1053 (22.4%) | 3643 (77.6%) | |
| No | 6558 (58.3%) | 2138 (32.6%) | 4420 (67.4%) | |
| Stress during the COVID-19 pandemic | | | | <0.001 |
| High | 2235 (19.9%) | 911 (40.8%) | 1324 (59.2%) | |
| Moderate | 4025 (35.8%) | 1308 (32.5%) | 2717 (67.5%) | |
| Low | 4994 (44.4%) | 972 (19.5%) | 4022 (80.5%) | |
| ADHD symptoms | | | | <0.001 |
| Yes | 579 (5.1%) | 385 (66.5%) | 194 (33.5%) | |
| No | 10675 (94.9%) | 2806 (26.3%) | 7869 (73.7%) | |
| Depression | | | | <0.001 |
| Moderate to severe | 1703 (15.1%) | 1050 (61.7%) | 653 (38.3%) | |
| Mild | 2970 (26.4%) | 1088 (36.6%) | 1882 (63.4%) | |
| Normal | 6581 (58.5%) | 1053 (16.0%) | 5528 (84.0%) | |
| Anxiety | | | | <0.001 |
| Moderate to severe | 1033 (9.2%) | 664 (64.3%) | 369 (35.7%) | |
| Mild | 2633 (23.4%) | 1176 (44.7%) | 1457 (55.3%) | |
| Normal | 7588 (67.4%) | 1351 (17.8%) | 6237 (82.2%) | |
| Insomnia | | | | <0.001 |
| Moderate to severe | 758 (6.7%) | 458 (60.4%) | 300 (39.6%) | |
| Subthreshold | 3181 (28.3%) | 1456 (45.8%) | 1725 (54.2%) | |
| Normal | 7315 (65.0%) | 1277 (17.5%) | 6038 (82.5%) | |
| PTSD | | | | <0.001 |
| Yes | 952 (8.5%) | 666 (70.0%) | 286 (30.0%) | |
| No | 10302 (91.5%) | 2525 (24.5%) | 7777 (75.5%) | |

Abbreviations: PIU, Problematic internet use; ADHD symptoms, Symptoms of attention deficit and hyperactivity; COVID-19, Coronavirus disease 2019; PTSD, Post-traumatic stress disorder.

^a χ^2 tests were used to compare the prevalence of PIU in different populations.

PTSD as continuous variables. Significance level was set at $P < 0.05$ and all tests were 2-sided. We used SPSS statistical software version 23 (IBM Corp) for all statistical analyses.

3. Results

3.1. Demographics

The 11,254 university students ranged from 15 to 35 years old with a mean (SD) age of 20.0 (1.3) years and included 4,054 males (36.0%). Table 1 provides other details of this sample including that 46.3% (5215) had quarantine experience, 0.7% (76) were confirmed or suspected COVID-19 infected patients or close contacts and 0.7% (80) had family members who were confirmed or suspected COVID-19 infected patients or close contacts.

3.2. Prevalence of PIU among different populations

Overall, 28.4% (95% CI, 27.5%-29.2%) (3191) of participants met the PIU assessment criteria, and PIU was significantly higher, but not impressively higher except among graduates (37.5%), among males (30.9%), students aged 15 to 20 years (28.9%), participants with a college or higher degree (30.4%), and participants with a higher monthly family income (30.4%). We also found higher PIU rates among participants who experienced quarantine (30.0%), participants who were confirmed infected with COVID-19, suspected cases, or close contacts by themselves (55.3%) or their family members (46.3%), and among participants feeling high (40.8%) or moderate (32.5%) stress

Table 2
Prevalence of Mental Illness Symptoms in Subgroups with or without Symptoms of Attention Deficit and Hyperactivity.

| | No. (%) | | P value ^a |
|--|----------------------------------|--|----------------------|
| | With ADHD symptoms (n=579, 5.1%) | Without ADHD symptoms (n=10675, 94.9%) | |
| Depression | | | <0.001 |
| Moderate to severe | 326 (56.3%) | 1377 (12.9%) | |
| Mild | 153 (26.4%) | 2817 (26.4%) | |
| Normal | 100 (17.3%) | 6481 (60.7%) | |
| Anxiety | | | <0.001 |
| Moderate to severe | 239 (41.3%) | 794 (7.4%) | |
| Mild | 194 (33.5%) | 2439 (22.8%) | |
| Normal | 146 (25.2%) | 7442 (69.7%) | |
| Insomnia | | | <0.001 |
| Moderate to severe | 178 (30.7%) | 580 (5.4%) | |
| Subthreshold | 236 (40.8%) | 2945 (27.6%) | |
| Normal | 165 (28.5%) | 7150 (67.0%) | |
| PTSD | | | <0.001 |
| Yes | 226 (39.0%) | 726 (6.8%) | |
| No | 353 (61.0%) | 9949 (93.2%) | |
| Any mental illness symptoms^b | | | <0.001 |
| Yes | 508 (87.7%) | 5408 (50.7%) | |
| No | 71 (12.3%) | 5267 (49.3%) | |

Abbreviations: ADHD symptoms, Symptoms of attention deficit and hyperactivity; PTSD, Post-traumatic stress disorder.

^a χ^2 tests were used to compare the prevalence of mental illness symptoms in subgroups with or without symptoms of attention deficit hyperactivity disorder.

^b Having any depression, anxiety, insomnia, PTSD symptoms; moderate to severe and mild depression were defined as having depression symptoms, moderate to severe and mild anxious were defined as having anxiety symptoms, moderate to severe and subthreshold insomnia were defined as having insomnia symptoms, positive PTSD was defined as having PTSD symptoms.

during the pandemic. In addition, the prevalence of PIU was higher among respondents who received psychological interventions during the pandemic (37.8%) and who had ADHD (66.5%), depression (moderate to severe, 61.7%; mild, 36.6%), anxiety (moderate to severe, 64.3%; mild, 44.7%), insomnia (moderate to severe, 60.4%; subthreshold, 45.8%) or PTSD symptoms (70.0%). In contrast, a lower prevalence of PIU was found amongst individuals who lived in Hubei Province during the pandemic (27.2%), individuals who acquired some psychological knowledge during the pandemic (27.2%), and individuals who exercised regularly during the pandemic (22.4%).

3.3. ADHD symptoms rate and co-occurring with other mental illness symptoms

5.1% (579) of participants met the ADHD symptoms assessment criteria. The prevalence rates of depression (moderate to severe, 56.3%; mild, 26.4%), anxiety (moderate to severe, 41.3%; mild, 33.5%), insomnia (moderate to severe, 30.7%; subthreshold, 40.8%) and PTSD symptoms (39.0%) were higher among participants with ADHD symptoms. Similarly, having any depression, anxiety, insomnia, and PTSD symptoms was more common in individuals with ADHD symptoms and the co-occurring rate was 87.7%. Table 2 presents detailed results of ADHD symptoms co-occurring with other mental illness symptoms.

3.4. Association of ADHD symptoms and PIU

This study indicated that the presence of ADHD symptoms was positively associated with PIU. The unadjusted OR of ADHD symptoms for PIU individuals was 5.57 (95% CI, 4.66-6.65). The adjusted OR reduced slightly from model 1 to model 2. However, adjusting for psychological factors in model 3 substantially reduced the adjusted OR to 2.31 (95% CI, 1.89-2.83).

Model 2, which adjusted for demographics and epidemic-related factors, showed that confirmed or suspected COVID-19-infected patients or those having close contacts with patients demonstrated a higher risk for PIU (OR: 1.90, 95% CI, 1.15-3.13). In contrast, acquiring some psychological knowledge during the pandemic was a protective factor for PIU (OR: 0.88, 95% CI, 0.81-0.96). However, a history of having received a psychological intervention during the pandemic was associated with PIU (OR: 1.46, 95% CI: 1.20-1.78).

In the fully adjusted model 3, male students, graduates and individuals with a higher monthly family income showed a higher risk for PIU, while participants more than 20 years old and with less than a college degree had a lower risk. Respondents who lived in Hubei Province during the pandemic (OR: 0.89, 95% CI: 0.81-0.98) and respondents who exercised regularly during the pandemic (OR: 0.68, 95% CI: 0.62-0.75) had a lower risk of PIU. Participants who felt high (OR: 1.45, 95% CI: 1.27-1.64) or moderate stress (OR: 1.45, 95% CI: 1.30-1.61) during the pandemic had higher risks than those feeling low stress. In addition, individuals with depression (moderate to severe, OR, 2.25 [1.87-2.71]; mild, OR, 1.53 [1.35-1.75]), anxiety (moderate to severe, OR, 1.55 [1.24-1.93]; mild, OR, 1.66 [1.45-1.89]), insomnia (moderate to severe, OR, 2.00 [1.65-2.44]; subthreshold, OR, 2.10 [1.89-2.34]), PTSD symptoms (OR: 1.87, 95% CI: 1.54-2.27) were susceptible to PIU compared with those without these 4 psychological conditions. Table 3 presents detailed results of the logistic regression analyses.

To further examine the association of ADHD symptoms and PIU, we conducted multiple linear regression of IAT scores as a continuous variable and ADHD symptoms and other mental health symptoms as independent variables. The final stepwise multiple linear regression

Table 3
Logistic Regression Analyses of the Association between Symptoms of Attention Deficit and Hyperactivity and Problematic Internet Use.

| Variables | OR (95% CI) | | |
|--|----------------------|----------------------|----------------------|
| | Model 1 ^a | Model 2 ^b | Model 3 ^c |
| ADHD symptoms | | | |
| Yes | 5.52 (4.62-6.61) ** | 4.62 (3.84-5.56) ** | 2.31 (1.89-2.83) ** |
| No | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Gender | | | |
| Male | 1.28 (1.17-1.40) ** | 1.36 (1.24-1.49) ** | 1.39 (1.26-1.53) ** |
| Female | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Age, y | | | |
| >20 | 0.81 (0.73-0.89) ** | 0.76 (0.69-0.84) ** | 0.72 (0.65-0.80) ** |
| 15-20 | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Education level | | | |
| Less than college | 0.65 (0.59-0.72) ** | 0.66 (0.60-0.74) ** | 0.63 (0.57-0.70) ** |
| College or higher | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Graduation | | | |
| Yes | 1.63 (1.31-2.03) ** | 1.51 (1.20-1.89) ** | 1.62 (1.27-2.07) ** |
| No | 1 [Reference] | 1 [Reference] | 1 [Reference] |
| Monthly family income, ¥ | | | |
| >10,000 | NA | 1.15 (1.03-1.29) * | 1.19 (1.05-1.34) * |
| ≤10,000 | NA | 1 [Reference] | 1 [Reference] |
| Living area during the COVID-19 pandemic | | | |
| Hubei Province | | 0.89 (0.81-0.97) * | 0.89 (0.81-0.98) * |
| Other provinces | | 1 [Reference] | 1 [Reference] |
| Confirmed/suspected COVID-19 or close contacting with patients | | | |
| Yes | | 1.90 (1.15-3.13) * | NA |
| No | | 1 [Reference] | NA |
| Exercising during the COVID-19 pandemic | | | |
| Yes | | 0.63 (0.57-0.69) ** | 0.68 (0.62-0.75) ** |
| No | | 1 [Reference] | 1 [Reference] |
| Stress during the COVID-19 pandemic | | | |
| High | | 2.62 (2.34-2.94) ** | 1.45 (1.27-1.64) ** |
| Moderate | | 2.04 (1.85-2.25) ** | 1.45 (1.30-1.61) ** |
| Low | | 1 [Reference] | 1 [Reference] |
| Acquiring some psychological knowledge during the COVID-19 pandemic | | | |
| Yes | | 0.88 (0.81-0.96) * | NA |
| No | | 1 [Reference] | NA |
| Receiving psychological interventions during the COVID-19 pandemic | | | |
| Yes | | 1.46 (1.20-1.78) ** | 1.23 (1.00-1.52) |
| No | | 1 [Reference] | 1 [Reference] |
| Depression | | | |
| Moderate to severe | | | 2.25 (1.87-2.71) ** |
| Mild | | | 1.53 (1.35-1.75) ** |
| Normal | | | 1 [Reference] |
| Anxiety | | | |
| Moderate to severe | | | 1.55 (1.24-1.93) ** |
| Mild | | | 1.66 (1.45-1.89) ** |
| Normal | | | 1 [Reference] |

Table 3 (continued)

| Variables | OR (95% CI) | | |
|--------------------|----------------------|----------------------|----------------------|
| | Model 1 ^a | Model 2 ^b | Model 3 ^c |
| Insomnia | | | |
| Moderate to severe | | | 2.00 (1.65-2.44) ** |
| Subthreshold | | | 2.10 (1.89-2.34) ** |
| Normal | | | 1 [Reference] |
| PTSD | | | |
| Yes | | | 1.87 (1.54-2.27) ** |
| No | | | 1 [Reference] |

Abbreviations: ADHD symptoms, Symptoms of attention deficit and hyperactivity; COVID-19, Coronavirus disease 2019; PTSD, Post-traumatic stress disorder; NA, not available (variables that were not included in the final model of backward regression).

^a Adjusted for gender, age, education level, graduation and monthly family income.

^b Adjusted for living area during the COVID-19 pandemic, confirmed/suspected COVID-19 or close contacting with patients, family members who are confirmed/suspected COVID-19 or closing contacting with patients, experiencing quarantine, exercising during the COVID-19 pandemic, stress during the COVID-19 pandemic, acquiring some psychological knowledge during the COVID-19 pandemic and receiving psychological interventions during the COVID-19 pandemic in addition to the covariates in model 1.

^c Adjusted for depression, anxiety, insomnia and PTSD symptoms in addition to the covariates in model 2.

* p<0.05,
** p<0.001

model (F=411.59, p<0.001, R²=0.32) found that the severity of depression (β=0.12), insomnia (β=0.19), PTSD (β=0.09), especially ADHD (β=0.21) symptoms was associated with the degree of PIU when controlling for demographics and epidemic-related factors. Male (β=0.05), graduates (β=0.04), having a higher monthly family income (β=0.03), feeling stress during the pandemic (β=0.08) and receiving psychological interventions during the pandemic (β=0.02) had significantly higher scores on the IAT. Conversely, significantly lower scores were found in the IAT scores of individuals older than 20 years (β=-0.05), with less than a college degree (β=-0.08), living in Hubei Province during the pandemic (β=-0.02) and excising during the pandemic (β=-0.07). Table 4 presents detailed results of the linear regression analyses.

4. Discussion

This online cross-sectional survey of university students from universities in Wuhan, Hubei Province, China during the COVID-19 pandemic found that more than one quarter had PIU and that ADHD symptoms and other mental health problems were associated with PIU. Students who were male, were graduates, and individuals with a higher monthly family income were more susceptible to PIU, whereas those acquiring some psychological knowledge and exercising regularly during the pandemic were less likely to have PIU. The severity of ADHD and other mental illness symptoms was associated with the degree of PIU. Our findings can serve the purpose of making comprehensive intervention measures and consequently alleviate the adverse impact of the pandemic on university students.

Different assessment scales for PIU provide varying prevalence rates across different countries and among different groups. Previous studies reported 13.6% -17.3% PIU among university students in China (Chi et al., 2016; Wang et al., 2020; Yang et al., 2017), and the overall prevalence of PIU across European and Asian countries was 8.4% (Pal Singh Balhara et al., 2019) before the pandemic. Our prevalence of 28.4% PIU is slightly lower than the 36.0% rate earlier in the outbreak period (Dong et al., 2020), but relatively higher than before the

Table 4
Multiple Linear Regression Analyses of the Association between Symptoms of Attention Deficit and Hyperactivity, Other Mental Illness Symptoms and Problematic Internet Use.

| Variables | Unstandardized coefficients | | Standardized coefficients β | t | p value |
|---|-----------------------------|--------------|--------------------------------|-------|---------|
| | B | 95% CI for B | | | |
| ADHD symptoms | 0.24 | 0.22-0.26 | 0.21 | 21.25 | <0.001 |
| Depression | 0.34 | 0.26-0.41 | 0.12 | 8.81 | <0.001 |
| Insomnia | 0.50 | 0.44-0.56 | 0.19 | 16.89 | <0.001 |
| PTSD | 0.10 | 0.07-0.13 | 0.09 | 6.99 | <0.001 |
| Gender | | | | | |
| Male | 1.54 | 1.08-2.01 | 0.05 | 6.49 | <0.001 |
| Female | 0 [Reference] | | 0 [Reference] | | |
| Age, y | | | | | |
| >20 | -1.70 | -2.21(-1.19) | -0.05 | -6.54 | <0.001 |
| 15-20 | 0 [Reference] | | 0 [Reference] | | |
| Education level | | | | | |
| Less than college | -2.38 | -2.88(-1.87) | -0.08 | -9.26 | <0.001 |
| College or higher | 0 [Reference] | | 0 [Reference] | | |
| Graduation | | | | | |
| Yes | 3.08 | 1.88-4.29 | 0.04 | 5.02 | <0.001 |
| No | 0 [Reference] | | 0 [Reference] | | |
| Monthly family income, ¥ | | | | | |
| >10,000 | 1.10 | 0.52-1.69 | 0.03 | 3.71 | <0.001 |
| ≤10,000 | 0 [Reference] | | 0 [Reference] | | |
| Living area during the COVID-19 pandemic | | | | | |
| Hubei Province | -0.69 | -1.15(-0.23) | -0.02 | -2.95 | 0.003 |
| Other provinces | 0 [Reference] | | 0 [Reference] | | |
| Exercising during the COVID-19 pandemic | | | | | |
| Yes | -2.06 | -2.51(-1.61) | -0.07 | -8.95 | <0.001 |
| No | 0 [Reference] | | 0 [Reference] | | |
| Stress during the COVID-19 pandemic | 0.41 | 0.32-0.50 | 0.08 | 9.33 | <0.001 |
| Receiving psychological interventions during the COVID-19 pandemic | | | | | |
| Yes | 1.36 | 0.30-2.41 | 0.02 | 2.51 | 0.012 |
| No | 0 [Reference] | | 0 [Reference] | | |

Abbreviations: ADHD symptoms, Symptoms of attention deficit and hyperactivity; COVID-19, Coronavirus disease 2019; PTSD, Post-traumatic stress disorder. Adjusted for gender, age, education level, graduation, monthly family income, living area during the COVID-19 pandemic, confirmed/suspected COVID-19 or close contacting with patients, family members who are confirmed/suspected COVID-19 or closing contacting with patients, experiencing quarantine, exercising during the COVID-19 pandemic, stress during the COVID-19 pandemic, acquiring some psychological knowledge during the COVID-19 pandemic, receiving psychological interventions during the COVID-19 pandemic, depression, anxiety, insomnia and PTSD.

pandemic. We cannot account for those secular changes over more than half a year of this pandemic, but increased leisure-time internet use is associated with PIU (Gao et al., 2020). Individuals who lived in Hubei Province during the pandemic had a lower prevalence of PIU at 27.2% compared to Beijing, Tianjin, and Hebei Province at 36.6%. One possible contributor was that in June 2020, shortly before our online survey, a new COVID-19 outbreak occurred in Beijing and spread to Tianjin and other provinces. However, this new outbreak did not affect Hubei Province, especially Wuhan. This escape from a second epidemic wave might have contributed to the low prevalence of PIU in Hubei Province at this time.

The association of ADHD symptoms and PIU was consistent with numerous studies (Carli et al., 2013) including two Japanese university student studies showing that participants with ADHD symptoms had significantly higher scores on the IAT (Tateno et al., 2018; Tateno et al., 2016). Online video games can provide a continuous stream of stimulation and immediate rewards, which satisfy people with ADHD symptoms, who are bored with delayed gratifications combined with impaired working memory (Castellanos and Tannock, 2002; Diamond, 2005). However, excessive use of the Internet may induce ADHD symptoms, as shown in a prospective study of high-frequency engagement in digital media leading to higher odds of ADHD symptoms at follow-up (Ra et al., 2018). ADHD patients have multiple psychiatric comorbidities including depression, anxiety, sleep disorders, and intellectual disabilities (Faraone et al., 2015). Consistent with previous reports, we found that individuals with ADHD symptoms had co-occurring depression, anxiety, insomnia, and PTSD symptoms more often than individuals without ADHD symptoms. We adjusted for these co-occurring mental illness symptoms in the final logistic model and ADHD symptoms were still significantly associated with PIU. Similarly,

the severity of ADHD symptoms and other mental illness symptoms was associated with the degree of PIU, and moreover the standardized β coefficients for ADHD symptoms was highest among those in the linear regression model, which verified the important strength impact of ADHD symptoms on PIU. Furthermore, reinforcing behaviors such as gambling, video gaming, using social media, or surfing the Internet can reduce stress, anxiety, and depression (Blasi et al., 2019; Khantzian, 2013; Király et al., 2015). Thus, the ADHD symptoms associated with PIU may be part of a coping strategy for dealing with the stress of the COVID-19 pandemic and the associated depression, anxiety, insomnia, and PTSD (Pierce et al., 2020; Shi et al., 2020).

More frequent physical activity has been associated with less severe psychological symptoms among French college students during COVID-19 (Wathelet et al., 2020), which accords with our finding that exercising regularly could decrease the risk of PIU. Regular physical activity reduces stress hormone levels and stimulates endorphin production to relieve pain and enhance mood (Király et al., 2020).

4.1. Implications

The findings of this survey and analysis show the high burden of PIU among university students in Wuhan after long-term school closure and the association between PIU with ADHD symptoms and other mental symptoms, which highlights the importance of maintaining mental wellbeing among university students during the COVID-19 pandemic. Existing evidence also showed that the impact of COVID-19 associated stress and quarantine experience on PIU during pandemic. Our findings indicate that those acquiring psychological knowledge and exercising regularly during the pandemic were less likely to have PIU. Therefore, comprehensive interventions are needed for vulnerable students to

alleviate the adverse mental health impact of the pandemic.

4.2. Strength and limitations

Although our participants come from universities in Wuhan, they lived in 31 different province-level regions across China during the pandemic. Our study's large sample size and extensive geographic coverage are strengths. We identify two limitations. First, using screening self-reports rather than interviews using diagnostic criteria may have biased our estimates of PIU and ADHD prevalence. Second, we cannot determine causality between ADHD and PIU because of the inherent drawback of a cross-sectional design.

5. Conclusions

We found that the prevalence of PIU among university students in China during the COVID-19 pandemic was higher than that reported before the pandemic. The positive association between ADHD symptoms and PIU remained significant after controlling for demographic, epidemic-related and psychological factors including moderate to high stress levels and associated depression, anxiety, insomnia, and PTSD symptoms, which were all individually associated with PIU. Exercising regularly during the COVID-19 pandemic was identified as associated with lower university students' risk for PIU. We cannot draw any causal conclusions about PIU and ADHD symptoms. Indeed, people with ADHD symptoms before the COVID-19 pandemic may have a higher risk of developing PIU, while others without ADHD symptoms show an association between high levels of internet usage and ADHD symptoms as part of their coping strategy for the stress and symptoms resulting from the COVID-19 pandemic.

Authorship contribution statement

Lu L, Shi J and Bao YP designed this survey, commented on, and revised the manuscript, and made the final version. Zhao YM was responsible for data analysis and writing the initial draft. Jiang ZD, Guo SH, Lu SD, Lu Y, Huang GF contributed to recruiting the participants and data collection. Zhao YM, Guo SH, Wu P, Lu QD, Xu YY, Liu L, Su SZ, Shi L, Que JY, Sun Y, Sun YK, Deng JH, Meng SQ, Yan W, Yuan K, Sun SW, Yang L, Ran MS, Kosten TR, Strang J, Lu Y, Huang GF designed the questionnaire, commented on and revised the manuscript. All authors contributed to the final draft of the manuscript.

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Declaration of Competing Interest

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