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Research paper

Problematic Internet use and academic engagement during the COVID-19 lockdown: The indirect effects of depression, anxiety, and insomnia in early, middle, and late adolescence

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ABSTRACT

Background: During the COVID-19 pandemic, the transition of online learning introduces challenges for adolescents to engage in learning. The increased access and persistent Internet use could heighten the risk of problematic Internet use (PIU) that has been increasingly recognized as a risk factor for academic engagement. This study aims to investigate the direct and indirect relationships between PIU and academic engagement through psychopathological symptoms (i.e., depression, anxiety, insomnia) in early, middle, and late adolescence.

Methods: In all, 4852 adolescents (51.5% females; M_{age} = 13.80 ± 2.38) from different regions of Chinese mainland participated in the study and completed questionnaires.

Results: Depression and then insomnia as well as anxiety and then insomnia mediated the relationship between PIU and academic engagement. Anxiety exhibited a double-edged effect, that is, a positive relation with academic engagement directly and a negative relation with academic engagement indirectly through insomnia. Multigroup analyses showed that the indirect effects of PIU on academic engagement through depression and subsequent insomnia in middle and late adolescence were stronger than that in early adolescence, whereas the direct effect in early adolescence was stronger than that in middle adolescence.

Limitation: This study was cross-sectional in design and relied upon self-report measures.

Conclusion: These findings improve the understandings of how PIU relates to academic engagement through psychopathological symptoms and highlight developmental differences of adolescence.

1. Introduction

On March 11, 2020, World Health Organization (2020) declared the novel coronavirus (COVID-19) outbreak a pandemic. In response to this crisis, governments worldwide have implemented a series of control measures, such as school suspensions and distance learning (Király et al., 2020). Over 1 billion students globally had their education disrupted by school closures (Guterres, 2020) and most of them were forced to experience a transition from conventional to online learning (United Nations Educational, Scientific, & Cultural Organization, 2020). In China, more than 282 million students were confined at home and took online courses during the COVID-19 lockdown (Chinese Education Daily, 2020). Online learning has been amplified by the long-lasting effects of the COVID-19 (Chou and Chou, 2021). However, according to Duan et al. (2020), many parents, students, and teachers complained about the poor effectiveness of online learning during the pandemic. Students faced many difficulties, such as lack of face-to-face interactions and socialization, and distraction by social media and Internet-related issues (Cai et al., 2021; Zhao et al., 2021). Also, they were less likely to concentrate on and engage in online learning partly because of some problematic Internet use (PIU) behaviors (e.g., spending longer and longer time online; Duan et al., 2020). Nevertheless, the relation between PIU and academic engagement during the COVID-19 pandemic is yet to be empirically explored. Hence, this study aims to examine the

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direct and indirect effects of PIU on academic engagement, which helps design intervention programs on enhancing academic engagement.

1.1. PIU and academic engagement

Academic engagement is defined as a positive, fulfilling, and study-related state of mind (Schaufeli et al., 2002a). As a developmental asset in adolescence, academic engagement is vital to academic achievement, school adaptation, and psychological well-being (Wang et al., 2019). Thus, the influential factors and mechanisms related to academic engagement should be further understood to guide interventions (Molin-Karakoc and Ikola, 2019). The theory of school engagement identifies individual characteristics as a key factor in academic engagement (Fredricks et al., 2004), including cognitive, emotional, and behavioral characteristics; PIU is identified as a behavioral characteristic. Among the influential factors, PIU has been increasingly examined as a risk one since the worldwide surge in the Internet use a decade ago (Mo et al., 2020; Zhang et al., 2018). Besides, Internet use and academic activities have become virtually inseparable during the pandemic, which may exaggerate PIU because increased access and persistent Internet use increase the risk of developing an overreliance on the Internet (Moreno et al., 2013). Therefore, it is necessary to consider PIU when exploring the mechanisms of academic engagement, especially during the pandemic.

PIU is conceptualized as an individual's inability to control Internet use that leads to feelings of distress and functional impairment (Shapira et al., 2000). In China, 17.3% of the adolescents aged below 18 years old reported PIU (China Internet Network Information Center, 2020). This behavior is related to many adverse influences, such as emotional problems, sleep disturbances, and academic failures (Paez et al., 2020; Seo et al., 2016). Wang (2015) found that PIU was negatively linked to academic engagement. Zhang et al. (2018) supported a similar finding that PIU predicted a decline in academic engagement longitudinally. Adolescents spending excessive time online tend to neglect or procrastinate their tasks, thereby reducing their academic engagement (Aznar-Díaz et al., 2020). These empirical studies have pinpointed the negative effect of PIU on academic engagement.

However, during the period of the school closures triggered by the COVID-19 pandemic, Internet use for learning and recreation has become virtually inseparable, which heightens the risk of PIU (Zhao et al., 2021). The pandemic along with the transition from traditional face-to-face learning to online learning may render different results in the relation between PIU and academic engagement. In addition, the mechanisms underlying this relation remain largely unexplored. During the pandemic, adolescents with PIU may suffer from severe psychopathological symptoms (Gecaite-Stonciene et al., 2021), and decrease academic engagement (Cai et al., 2021). Thus, this study focuses on the indirect effects of depression, anxiety, and insomnia between PIU and academic engagement.

1.2. Depression, anxiety, and insomnia as potential mediators

The adjustment erosion hypothesis (Moilanen et al., 2010) provides a valuable theoretical basis for examining the association between PIU and academic engagement via depression, anxiety, and insomnia. This theory posits that initial externalizing problems (e.g., PIU) increase future susceptibility to internalizing symptoms (e.g., depression) and, in turn, reduce academic engagement. Specifically, PIU may result in poor family and peer relationships, both of which may lead to elevated depression and anxiety and then leave adolescents vulnerable to insomnia; ultimately, the above psychopathological symptoms may limit the opportunities for learning, thereby impeding academic engagement (Moilanen et al., 2010). Additionally, adolescents need to turn off Internet applications irrelevant to study for better focusing on learning. However, adolescents with PIU may experience highly negative arousal emotions when Internet use for recreation is restricted (Baker et al., 2004), which may interfere with academic engagement.

PIU not only affects academic engagement (Seo et al., 2016) but also triggers psychopathological symptoms (Paez et al., 2020), especially during the pandemic (Majumdar et al., 2020). Systematic reviews showed that PIU is related to depression, anxiety, and insomnia in adolescence (Elhai et al., 2017; Mac Cárthaigh et al., 2020). Longitudinal studies also suggested that PIU or PIU-related variables (e.g., excessive Internet use, problematic smartphone use) predicted later depression (Coyne et al., 2019), anxiety (Paez et al., 2020), and insomnia (Chen and Gau, 2016). According to coping style theory (Lazarus and Folkman, 1984), PIU as a maladaptive coping strategy allows individuals to escape from stressful life events that may curtail their real-life relationships and deprive them of regulation skills, thereby reducing their mental health (Moritz et al., 2016). Cain and Gradisar (2010) argued that exposure to light emission from electronic screens before sleep and incoming messages during sleep, as a result of PIU, were related to arousal problems (e.g., depression, anxiety) and insomnia. Overall, PIU may be positively linked to depression, anxiety, and insomnia.

In the integrative model of academic engagement (Wang et al., 2019), psychological factors were influential in academic engagement. Adolescents with depressive or anxiety symptoms often face difficulties in redirecting their focus on studies owing to the lack of regulation strategies and abilities (Valiente et al., 2008). Correspondingly, low-degree depression and anxiety were associated with high academic engagement (Pokhrel et al., 2020). Moreover, insomnia predicted low academic engagement in Wong et al. (2013) because insomnia impairs individual attention and reduce cognitive processing, both of which are crucial for learning (Alhola and Polo-Kantola, 2007). As a result, adolescents with insomnia cannot sustain their daytime functioning and disengage from academic activities (Vernon et al., 2015). Above all, depression, anxiety, and insomnia may be negatively related to academic engagement.

Regarding the relations between depression, anxiety, and insomnia, depression and anxiety are highly related to each other, often being the highest comorbidity among all mental disorders (Kessler et al., 2005). First, they include several overlapping symptoms, such as tiredness and sleep problems (American Psychiatric Association, 2013). Second, depressive and anxiety symptoms can easily influence each other (Hoffart et al., 2021). Third, emotion regulation has been proposed as a transdiagnostic construct or an underlying mechanism of depression and anxiety (Adrian et al., 2019). In addition to the similarities, depression and anxiety have some distinct features. For example, depressive people tend to ruminate about the failures of past experiences whilst anxious people tend to worry about the uncertainty of future events (Nitschke et al., 2001). Therefore, to better understand the unique symptoms of depression and anxiety (instead of the overlapping ones) as well as their interdependent associations, depression and anxiety should be examined in the same model, suggested by existing literature (Epkins and Seegan, 2015; Xu et al., 2021). In the present study, we compare the relations between depression vs. anxiety and academic engagement after controlling the correlation between depression and anxiety.

Moreover, insomnia is viewed as a concomitant symptom and dysfunctional consequence of depression and anxiety, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM–5; American Psychiatric Association, 2013). Depression and anxiety predicted insomnia within daily patterns and longitudinally (Cousins et al., 2011; Rutten et al., 2017). Treatments for depression and anxiety also reduced insomnia symptoms (Mason and Harvey, 2014). Additionally, Rutten et al. (2017) found that depression and anxiety independently predicted insomnia at follow-up but were not predicted by baseline insomnia. Adolescents with depression and anxiety are prone to negative thinking, especially during the pre-sleep period, thereby delaying their sleep onset and exacerbating insomnia (Olatunji et al., 2013). In sum, the relation between PIU and academic engagement may be through depression and anxiety parallelly, and then insomnia.

1.3. Adolescent developmental differences

Adolescence is commonly referred to the stage of growth between 10 and 18 years of age (Curtis, 2015). Given that adolescence marks a period of rapid and profound changes in biological functioning and social contexts (Dahl et al., 2018), understanding age-related differences and processes in psychological and behavioral characteristics are necessary. According to the previous studies examining the entire span of adolescence (Liu et al., 2022), adolescence can be divided into three stages: early (10–12 years old), middle (13–15 years old), and late (16–18 years old).

The development from early to middle to late adolescence parallels with one's transition from elementary to middle to high school in China, which involves changes in school settings and academic requirements (Zhang et al., 2019). Learning is more challenging and competitive for middle adolescents than for early adolescents and the former ones face higher expectations from parents and experience greater academic stress, which may impact their academic engagement (Masten et al., 2005). In addition, the severity of PIU, depression, and anxiety often increases along with age from early to late adolescence (especially from early to middle adolescence) (Cerniglia et al., 2019).

Regarding the relation among PIU, depression, anxiety, insomnia, and academic engagement, it may vary by adolescent developmental stages. Specifically, the association between depression and academic engagement was stronger in early than in middle adolescence (Zhang et al., 2019). Williams and Hagger-Johnson (2017) suggested that academic behavior in early adolescence is more vulnerable to delinquent behaviors than in late adolescence. Therefore, the association between academic engagement and the risk factors may be different in three stages.

1.4. The present study

The association between PIU and academic engagement requires further explorations: whether and how depression, anxiety, and insomnia mediate this association and whether developmental differences can be observed across early, middle, and late adolescence. This is the first study to compare adolescent developmental stages in the relations among PIU, depression, anxiety, insomnia, and academic engagement. This study hypothesizes an indirect effect model (Fig. 1) in a large sample of Chinese adolescents recruited during the COVID-19 lockdown, and proposes the following hypotheses: (1) PIU would be negatively associated with academic engagement; (2) depression and subsequent insomnia, and anxiety and subsequent insomnia would respectively mediate the association between PIU and academic engagement; (3) the direct and indirect effects on the relation between PIU and academic engagement would be stronger in early than in late adolescence. Several variables (i.e., adolescent age, gender, one-child) were controlled given their previously reported relations with PIU, depression, anxiety, insomnia, and academic engagement (Chen and Gau, 2016; Mo et al., 2020; Zhang et al., 2019).

2. Material and methods

2.1. Participants

A total of 5581 participants completed the questionnaires. To ensure that our results were based on valid responses, we embedded quality check items (i.e., Please choose "4") in the survey and used these items to exclude inattentive respondents, resulting in effective recovery of 86.9%. The final sample included 4852 adolescents aged between 10 and 18 years of age (M_{age} = 13.80 ± 2.38). These participants were divided into three age groups: early (N = 1524; M_{age} = 10.96 ± 0.82, 10–12 years), middle (N = 1809; M_{age} = 13.78 ± 0.75, 13–15 years), and late adolescence (N = 1519; M_{age} = 16.66 ± 0.66, 16–18 years). They were from 37 primary and secondary schools across different regions of the Chinese mainland, including the regions of North China (e.g., Tianjin), Middle China (e.g., Henan), South China (e.g., Guangdong), East China (e.g., Anhui), Southwest China (e.g., Sichuan), and Northwest China (e.g., Ningxia). Approximately 51.5% were females and in each age group, the proportions of gender were similar: 49.5%, 51.6%, and 53.3% females in early, middle, and late adolescence, respectively. Additionally, 50.4% of the participants were the only children in their families.

2.2. Procedures

Data were collected through an e-questionnaire website called "Questionnaire Star" during the COVID-19 pandemic between April 23rd and May 7th, 2020. After receiving the permissions from 37 participating schools, we sent the e-questionnaires to the teachers and explained to them the purpose and ethical principles of this scientific research. Later, these teachers redistributed the e-questionnaires to the students and their guardians. The participants were asked about their perceptions and behaviors during the COVID-19 lockdown. All students and their parents consented to participate in the study and were informed that they are free to withdraw at any time. The email address of the research team was written on the first page of the e-questionnaire in case participating families required support or assistance. All materials and procedures were approved by the Research Ethical Committee of the corresponding author.

2.3. Measures

2.3.1. PIU

The 26-item Chinese Internet Addiction Scale-Revised (CIAS-R; Chen et al., 2003) was used to assess PIU. This scale comprised five subscales: compulsive use, withdrawal symptoms, tolerance symptoms,

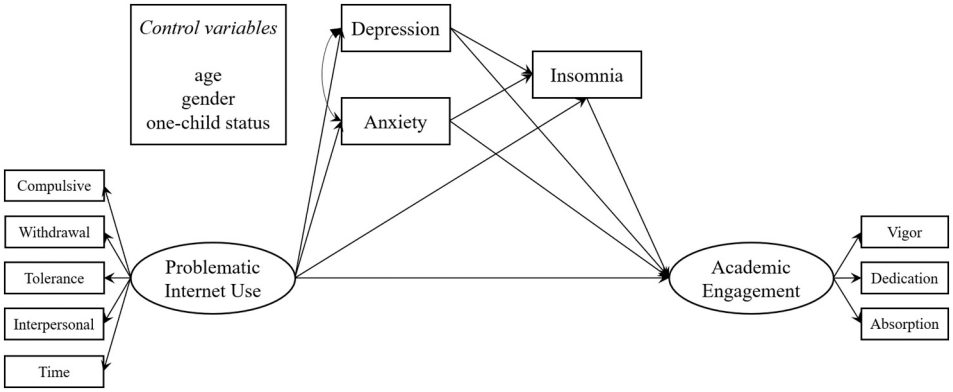

Fig. 1. Hypothesized chained mediation model.

interpersonal and health-related problems, and time management problems. Sample item is "Feel depressed once not online for a while". Responses were made on a 4-point Likert-type scale ranging from 1 (*not like me at all*) to 4 (*completely like me*). Adolescents scoring 58 or above are classified as having PIU (Zhou et al., 2018). The CIAS-R has achieved high split-half reliability, test-retest reliability, and convergent validity among Chinese adolescents (Chen et al., 2003; Mak et al., 2014). The Cronbach's alpha values of the five subscales were 0.87, 0.87, 0.82, 0.90, and 0.83.

2.3.2. Depression

The Chinese version of the 20-item Self-Rating Depression Scale (SDS; Wang et al., 1999; Zung, 1965) was used to measure depressive symptoms. Sample items include "I feel downhearted and blue". Responses were rated on a 4-point Likert-type scale ranging from 1 (*none or little time*) to 4 (*most or all times*). The cut-off point for depression is an index score of 53, and higher scores indicated severer depressive symptoms; this scale has been validated among the Chinese population (Wang et al., 1999; Shen et al., 2021). The Cronbach's alpha value of SDS was 0.74.

2.3.3. Anxiety

The Chinese version of the 20-item Self-Rating Anxiety Scale (SAS; Wang et al., 1999; Zung, 1971) was used to measure anxiety symptoms. Sample items include "I feel more nervous and anxious than usual". Responses were rated on a 4-point Likert-type scale ranging from 1 (*none or little time*) to 4 (*most or all times*). The cut-off point for anxiety is an index score of 50, and higher scores suggested severer anxiety symptoms; this scale has been validated among the Chinese population (Wang et al., 1999; Shen et al., 2021). The Cronbach's alpha value of SAS was 0.79.

2.3.4. Insomnia

The Chinese version of the 8-item Athens Insomnia Scale (CAIS; Chiang et al., 2009; Soldatos et al., 2000) was used to assess insomnia. Sample items include "Awakening during the night". Responses were rated on a 4-point Likert-type scale ranging from 0 (*None*) to 3 (*Serious*). Respondents who score higher than 6 are classified as insomniacs, and higher scores indicated severer insomnia (Soldatos et al., 2003). The CAIS demonstrates great reliability and validity among the Chinese population (Chiang et al., 2009). This scale obtained a Cronbach's alpha value of 0.84.

2.3.5. Academic engagement

The Chinese version of the 17-item Utrecht Work Engagement Scale for Students (UWEC-S; Fang et al., 2008; Schaufeli et al., 2002b) was used to evaluate academic engagement including three subscales: vigor, dedication, and absorption. Sample item is "I find my studies to be full of meaning and purpose". Responses were rated on a 7-point Likert-type scale ranging from 1 (*never*) to 7 (*always*). This scale has satisfactory reliability and validity among Chinese students (Fang et al., 2008). The three subscales obtained Cronbach's alpha values of 0.96, 0.93, and 0.95, respectively.

2.4. Data analysis

Given that the online questionnaires did not allow the respondents to skip any items, there were no missing item-level data. Before any analyses, we examined all study variables for normality of distribution by skewness and kurtosis. The skewness ranged from −0.15 to 1.63, and the kurtosis ranged from −0.59 to 4.14, both of which are acceptable (|skewness| < 3 and |kurtosis| < 10; Kline, 2016). Descriptive and correlational analysis was computed using SPSS 21.0 and model testing was computed using Mplus 7.0.

First, considering three variables, depression, anxiety, and insomnia, were examined as observed variables, the measurement model was examined with two latent variables: PIU (indicated by five subscales: compulsive use, withdrawal symptoms, tolerance symptoms, interpersonal and health-related problems, and time management problems) and academic engagement (indicated by three subscales: vigor, dedication, and absorption). The model fitted the data well (χ^2 (19) = 780.13, CFI = 0.98, TLI = 0.98, RMSEA = 0.09, SRMR = 0.01) and all factor loadings exceeded 0.85. Second, structural equation modeling (SEM) was performed with control variables (i.e., age, gender, one-child), using the maximum likelihood estimation based on 5000 bootstrap replicates (Preacher and Hayes, 2008). The procedure yielded a point estimate of the indirect effect and its 95% bias-corrected confidence interval (CI). The indirect effect is deemed significant when the CI does not include zero (Muthén and Muthén, 2012). The effect size of the indirect effect was calculated with P_M and R^2 (Wen and Fan, 2015). The residual correlation between depression and anxiety was controlled given their high comorbidity. Third, a multigroup analysis was conducted to determine whether the indirect effect model examined in the second step was different across early, middle, and late adolescence. This analysis was first conducted to examine the equivalence of the measurement model between the subgroups (Δ CFI < 0.01; Cheung and Rensvold, 2002). Later, two models were compared for group differences: the restricted model with all factor loadings estimated to be equal across groups, and the unrestricted model with all factor loadings estimated to be free. A Wald test was performed to identify specific paths that differed by groups. Finally, model fit was evaluated by using multiple indices: CFI > 0.90, TLI > 0.90, RMSEA <0.08, and SRMR <0.08.

3. Results

3.1. Preliminary analysis

Table 1 presents the sociodemographic characteristics of PIU, depression, anxiety, insomnia, and academic engagement. According to the cut-off points described in the measures, the prevalence of PIU, depression, anxiety, and insomnia were 28.3%, 23.4%, 13.4%, and 11.2%, respectively. All variables varied by age groups (all *ps* < .001).

Table 2 shows the Pearson correlations of the variables. PIU was positively and significantly correlated with depression, anxiety, and insomnia but was negatively and significantly correlated with academic engagement. Also, depression, anxiety, and insomnia were positively and significantly correlated with one another but were negatively and significantly correlated with academic engagement. The correlation patterns provided preliminary support for the mediation analysis. In addition, the older was significantly correlated with higher PIU; the older, female, and non-only children were significantly correlated with higher depression, anxiety, and insomnia; the older and non-only children were significantly correlated with lower academic engagement. Age, gender, and one-child status were controlled in the following analyses.

3.2. SEM

PIU was negatively associated with academic engagement in the total effect (β = −0.44, p < .001). Fig. 2 illustrates the standardized coefficient of the indirect model. The model obtained a good fit (χ^2 (58) = 1800.38, CFI = 0.97, TLI = 0.95, RMSEA = 0.08, SRMR = 0.05). Given that one item (i.e., I have trouble sleeping at night) of the SDS and one item (i.e., I fall asleep easily and get a good night's rest; reverse-worded item) of the SAS were similar to insomnia symptoms, a model that excluded these items was analyzed. The model results of item-deleted variables and that of original variables were consistent, so the results with original variables were reported. PIU was positively associated with depression (β = 0.43, p < .001), anxiety (β = 0.46, p < .001), and insomnia (β = 0.14, p < .001). Depression (β = −0.49, p < .001) and insomnia (β = −0.14, p < .001) were negatively associated with academic engagement, whereas anxiety was positively associated with

Table 1
Sociodemographic characteristics of the study variables.

	Problematic Internet use		Depression		Anxiety		Insomnia		Academic engagement
	M (±*SD*)	*n* (%)	*M* (±*SD*)	*n* (%)	*M* (±*SD*)	*n* (%)	*M* (±*SD*)	*n* (%)	*M* (±*SD*)
Total	1.87 (±0.65)	1375 (28.3%)	1.72 (±0.51)	1135 (23.4%)	1.53 (±0.43)	652 (13.4%)	0.33 (±0.40)	543 (11.2%)	4.98(±1.37)
Age group (χ^2/*F*)	137.68***	180.09***	51.36***	38.77***	50.02***	51.36***	146.50***	101.80***	77.13***
Early adolescence	1.66 (±0.60)	251(16.5%)	1.61 (±0.48)	274(18.0%)	1.44 (±0.37)	127(8.3%)	0.19 (±0.29)	68(4.5%)	5.34(±1.38)
Middle adolescence	1.91 (±0.67)	545(30.1%)	1.78 (±0.54)	487(26.9%)	1.56 (±0.45)	273 (15.1%)	0.40 (±0.43)	265 (14.6%)	4.81(±1.42)
Late adolescence	2.04 (±0.61)	579(38.1%)	1.76 (±0.50)	374(24.6%)	1.58 (±0.44)	252 (16.6%)	0.40 (±0.41)	210 (13.8%)	4.83(±1.24)
Gender (χ^2/*F*)	0.15	0.07	19.21***	9.18**	5.67*	1.26	24.20***	12.97**	2.50
Male	1.88 (±0.66)	663(28.2%)	1.69 (±0.50)	506(21.5%)	1.51 (±0.42)	303 (12.9%)	0.31 (±0.38)	225(9.6%)	5.01(±1.41)
Female	1.87 (±0.64)	712(28.5%)	1.75 (±0.53)	629(25.2%)	1.54 (±0.43)	349 (14.0%)	0.36 (±0.41)	318 (12.7%)	4.95(±1.34)
One-child (χ^2/*F*)	3.39	6.88**	39.98***	8.98**	28.77***	9.03**	13.32***	3.57	24.99***
Only child	1.86 (±0.65)	652(26.7%)	1.68 (±0.51)	528(21.6%)	1.50 (±0.42)	293 (12.0%)	0.31 (±0.39)	253 (10.3%)	5.08(±1.41)
Non-only child	1.89 (±0.65)	723(30.0%)	1.76 (±0.51)	607(25.2%)	1.56 (±0.43)	359 (14.9%)	0.35 (±0.40)	290 (12.1%)	4.88(±1.33)

Note. *M* = Mean, *SD* = Standard Deviation. *$p < .05$, **$p < .01$; ***$p < .001$.

Table 2
Pearson correlations for the study variables.

Variable	1	2	3	4	5	6	7	8
Age	–							
Gender	0.03*	–						
One-child	−0.05**	0.08***	–					
Problematic Internet Use	0.22***	−0.01	0.03	–				
Depression	0.11***	0.06***	0.08***	0.42***	–			
Anxiety	0.13***	0.03*	0.08***	0.45***	0.79***	–		
Insomnia	0.21***	0.07***	0.05***	0.39***	0.53***	0.54***	–	
Academic Engagement	−0.14***	−0.02	−0.07***	−0.43***	−0.53***	−0.40***	−0.40***	–

Note. Gender: 1 = male, 2 = female; one-child: 1 = one child, 2 = non-one child. *$p < .05$; **$p < .01$; ***$p < .001$.

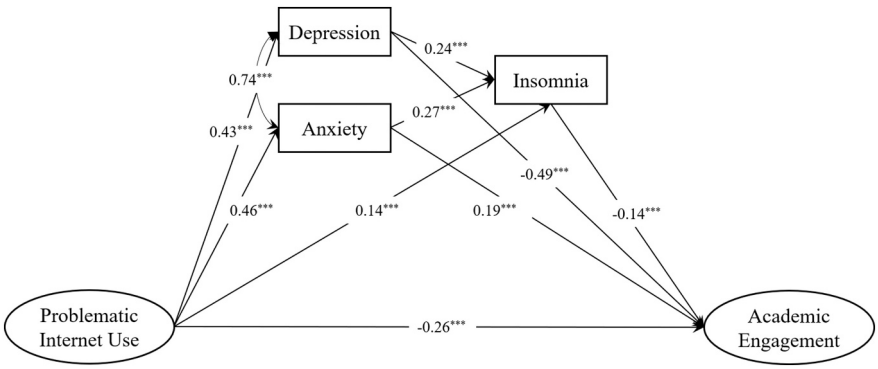

Fig. 2. Standardized path coefficients of the chain mediation model from problematic Internet use to academic engagement. The controlled variables are not shown in the figure. ***$p < .001$.

academic engagement (β = 0.19, $p < .001$). Depression was positively associated with anxiety (β = 0.74, $p < .001$). Depression (β = 0.24, $p < .001$) and anxiety (β = 0.27, $p < .001$) were positively associated with insomnia. Moreover, the direct association between PIU and academic engagement remained significant (β = −0.26, $p < .001$).

As shown in Table 3, the 95% bootstrap CIs of the three simple mediation effects of depression, anxiety, and insomnia between PIU and academic engagement did not include zero. Furthermore, the 95% bootstrap CI of the chained mediation effects of depression and subsequent insomnia, and anxiety and subsequent insomnia did not include zero. The indirect and the direct effects of anxiety had opposite signs (i.e., one is negative and the other positive), thereby indicating that the effect size ratio P_M could not be calculated. The R^2 of the model in the total sample was 0.359, suggesting that the mediating model accounted for 35.9% of the variance in academic engagement.

3.3. Multigroup analysis

A multigroup analysis was performed to test whether the model differed by age groups. First, the model was verified in three groups and showed adequate fit (early: χ^2 (58) = 439.25, CFI = 0.98, TLI = 0.97, RMSEA = 0.07, and SRMR = 0.02; middle: χ^2 (58) = 670.55, CFI = 0.97, TLI = 0.96, RMSEA = 0.08, and SRMR = 0.03; and late: χ^2 (55) = 501.61, CFI = 0.97, TLI = 0.96, RMSEA = 0.07, and SRMR = 0.03).

Table 3
Bootstrap confidence interval (CI) and effect size of the mediation model.

Mediation paths	Total sample			Early adolescence			Middle adolescence			Late adolescence		
	Estimate	95% CI	P_M	Estimate	95% CI	P_M	Estimate	95% CI	P_M	Estimate	95% CI	P_M
PIU→Dep→AE	−0.21	[−0.24, −0.19]	0.48	−0.13	[−0.16, −0.09]	0.31	−0.25	[−0.29, −0.21]	0.59	−0.22	[−0.27, −0.18]	0.49
PIU→Anx→AE	0.09	[0.06, 0.12]	–	0.04	[0.01, 0.07]	–	0.11	[0.06, 0.16]	–	0.10	[0.06, 0.14]	–
PIU→Ins→AE	−0.02	[−0.03, −0.01]	0.05	−0.01	[−0.02, −0.003]	0.03	−0.02	[−0.04, −0.01]	0.06	−0.02	[−0.03, −0.01]	0.04
PIU→Dep→Ins→AE	−0.02	[−0.02, −0.01]	0.03	−0.004	[−0.01, 0.00]	0.01	−0.02	[−0.03, −0.01]	0.05	−0.02	[−0.03, −0.01]	0.05
PIU→Anx→Ins→AE	−0.02	[−0.02, −0.01]	0.04	−0.01	[−0.02, −0.003]	0.03	−0.02	[−0.03, −0.01]	0.05	−0.02	[−0.03, −0.01]	0.04

Note. PIU = Problematic Internet Use; Dep = Depression; Anx = Anxiety; Ins = Insomnia; AE = Academic Engagement.
P_M = ratio of the indirect effect to the total effect. Mediation path PIU→Anx→AE is an inconsistent mediation model without P_M.

Second, the metric invariance of the measurement model was proved among three groups (baseline model: χ^2 (57) = 789.26, CFI = 0.98, TLI = 0.98, RMSEA = 0.09, and SRMR = 0.02; metric model: χ^2 (69) = 863.59, CFI = 0.98, TLI = 0.98, RMSEA = 0.08, and SRMR = 0.03; Δ CFI = 0.001 < 0.01). Third, the unrestricted model better fitted than the restricted model (unrestricted model: χ^2 (198) = 1900.08, CFI = 0.97, TLI = 0.96, RMSEA = 0.07, and SRMR = 0.03; restricted model: χ^2 (216) = 2068.17, CFI = 0.97, TLI = 0.96, RMSEA = 0.07, and SRMR = 0.05; Δ χ^2 = 168.09, Δ *df* = 18, $p < .001$), indicating that the indirect effect model varied in three age groups. Table 3 presents the 95% bootstrap CIs of the indirect effects. The models in the early, middle, and late adolescence explained 31.1%, 36.4%, and 37.2% of the variance in academic engagement, respectively.

A Wald test was performed to compare path coefficients in the three groups. All paths between middle and late adolescence were not significantly different (*ps* > .05). The significantly different paths between early and middle adolescence, and between early and late adolescence were bold in Fig. 3. Specifically, path coefficients of PIU to depression, PIU to anxiety, and depression to insomnia were significantly higher in middle and late than in early adolescence (*ps* < .001). Moreover, path coefficients of PIU to insomnia and depression to academic engagement were significantly higher in middle than in early adolescence ($p = .004$; $p = .03$), whilst path coefficients of PIU to academic engagement were significantly higher in early than in middle adolescence ($p = .005$). The direct effect between PIU and academic engagement was stronger in early than in middle adolescence. Regarding the indirect effects, PIU→depression→insomnia→academic engagement, PIU→depression→academic engagement, and PIU→anxiety→academic engagement were significantly stronger in middle and late adolescence than in early adolescence (*ps* < .05).

4. Discussion

Academic engagement is one of the major developmental assets to promote adolescent psychosocial functioning. Hence, identifying factors that influence academic engagement is essential for interventions. During the COVID-19 lockdown, many students cannot actively engage in their online classes partly owing to PIU. Previous studies showed that PIU, which peaks during adolescence, was harmful to both academic engagement and mental health, but the potential mechanisms or differences of such effects across adolescent developmental stages are yet to be clarified. This study explored the direct and indirect paths from PIU to academic engagement across early, middle, and late adolescence.

The main findings are as follows: (1) PIU was negatively associated with academic engagement; (2) depression and subsequent insomnia, and anxiety and subsequent insomnia respectively mediated the association between PIU and academic engagement; (3) anxiety was positively related to academic engagement directly whereas was negatively related to academic engagement through insomnia; (4) the chained mediating effect of PIU on academic engagement via depression and insomnia in middle and late was stronger than that in early adolescence, whereas the direct effect of PIU on academic engagement in early was stronger than that in middle adolescence. These findings are discussed below.

Consistent with previous studies (Wang, 2015; Zhang et al., 2018), this research showed that PIU was negatively related to academic engagement in the special period of the COVID-19 pandemic. During the pandemic, adolescents often increase their time spent online for courses, and other recreational purposes as well. Unlike face-to-face classes, adolescents who study online are not monitored by teachers (Duan et al., 2020), thereby giving them easy access to recreation, such as playing games during classes. Increased access and persistent Internet use both increase the risk of developing PIU (Moreno et al., 2013). Adolescents

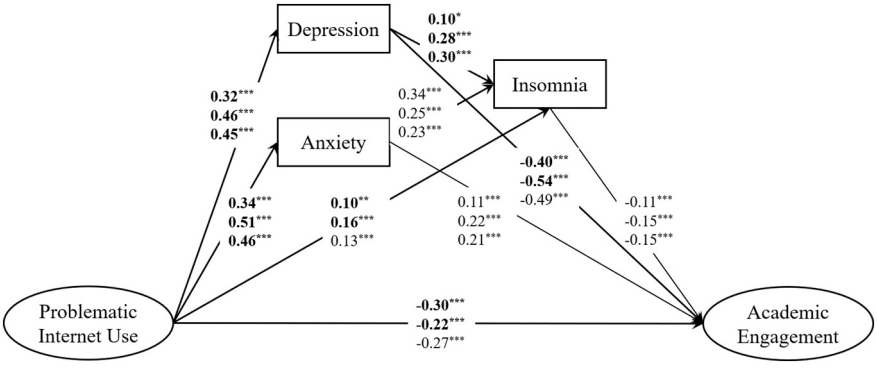

Fig. 3. Standardized path coefficients of the chain mediation model in early, middle and late adolescence. Path coefficients of early adolescence are positioned at the first line, path coefficients of middle adolescence are positioned at the second line, and path coefficients of late adolescence are positioned at the third line. Values and lines in bold indicate significant differences in path coefficients among age groups. *$p < .05$; **$p < .01$; ***$p < .001$.

who spend increasing time online show reduced time on academic purposes and a decreased level of academic aspirations (Mo et al., 2020). The loss of control over and preoccupation with Internet use may impair the ability of adolescents to fulfill their academic responsibilities (Salmela-Aro et al., 2017). Therefore, adolescents with high PIU may be unable to focus on learning, show lack of motivation, and have poor memory (Park et al., 2017). Moreover, they tend to procrastinate and avoid learning (Aznar-Díaz et al., 2020), which may lower academic engagement.

Depression and subsequent insomnia acted as chained mediators between PIU and academic engagement. PIU was related to high-level depression, high-level insomnia, and in turn related to low-level academic engagement, which is in line with previous studies (Coyne et al., 2019; Rutten et al., 2017; Scotta et al., 2020). Adolescents who spend excessive time on the Internet (e.g., for gaming, chatting, watching videos) may develop depressive symptoms as they are excessively exposed to unrealistic portrayals of others that may elicit upward social comparisons (Zheng et al., 2020) and low self-esteem (Mo et al., 2020). PIU also takes up the time spent with peers and families, affecting adolescents' real-life relationships. Adolescents who lack social support and affection from their peers and families may easily slide into negative moods, fall into a feedback loop of negative thinking and emotions (Olatunji et al., 2013), and then may be likely to become depressed. For depressive adolescents, their intrusive and negative thoughts at bedtime may lead to delayed sleep onset and exacerbate insomnia symptoms (Hellberg et al., 2019). Ultimately, insomnia may reduce academic engagement because sleep is an optimal state of brain activity linked to neurocognitive functioning, which is crucial for one to maintain cognitive performance throughout the day (Dewald et al., 2010). Therefore, insomnia that reduces general alertness, impairs one's attention, and slows down cognitive processing (Alhola and Polo-Kantola, 2007), may finally lower academic engagement.

Similarly, anxiety and subsequent insomnia also acted as chained mediators between PIU and academic engagement. PIU was related to high-level anxiety, high-level insomnia, and in turn related to low-level academic engagement, which accords with prior work (Paez et al., 2020; Rutten et al., 2017; Scotta et al., 2020). PIU may be positively related to anxiety among adolescents because of the function PIU—a maladaptive coping strategy that can deprive adolescents of opportunities to learn and regulate their emotions (Moritz et al., 2016). When faced with stressful events, the deficits in emotional regulation can easily render adolescents to the feelings of anxiety (Adrian et al., 2019). Moreover, PIU is functioned as a compulsive leisure activity that is developed as a process of mood enhancement (Chou and Hsiao, 2000). However, with the worsen symptoms of PIU (e.g., failure to cut back Internet use), the inability to control such automatized behavior may result in heightened levels of anxiety (Baker et al., 2004). Similar to depression, anxiety is a precursor for insomnia with growing worry and ruminative thinking during the pre-sleep period (Akram et al., 2019). This pre-sleep state arousal can subsequently cause insomnia (Cain and Gradisar, 2010) and ultimately reduce the academic engagement of adolescents (Dewald et al., 2010).

Moreover, anxiety showed a double-edged effect on academic engagement. Specifically, the effects of PIU→anxiety→insomnia→academic engagement and PIU→anxiety→academic engagement were contradictory—PIU was related to higher anxiety, higher insomnia, and ultimately related to lower academic engagement as well as PIU was related to higher anxiety and then related to higher academic engagement.

The findings extend the effect of anxiety on top of previous studies. In the first place, Pokhrel et al. (2020) suggested that anxiety, as a psychological disorder, adversely affected academic engagement and other school-related performance, which contradicts the present finding. One potential explanation is that Pokhrel et al. (2020) did not consider depression in the model, which overlaps with anxiety and may account for its effect. We conducted a supplementary analysis and found that anxiety was associated with low academic engagement in our sample if we did not enter depression into the model. However, given that depression and anxiety are highly comorbid (Kessler et al., 2005) and they have distinct influences on adolescents' adjustment (Epkins and Seegan, 2015), it is necessary to include depression in the model when exploring anxiety. Further studies on examining the effect of anxiety on academic engagement are needed, especially considering the effect of depression simultaneously.

In the second place, Hasty et al. (2020) argued that anxiety could propel academic engagement, and adolescents with higher anxiety invested more time in learning compared with those with lower anxiety. Since learning may function as a regulation strategy for reducing anxiety (Yerdelen et al., 2016), anxious adolescents may engage themselves more in learning. In addition, anxious adolescents may adopt compensatory strategies, such as enhanced effort and increased use of processing resources, to ensure good performance (Eysenck et al., 2007), thereby increasing academic engagement (Yerdelen et al., 2016). The anxiety scale used in this study did not represent a diagnosis of anxiety disorder, and only 13.4% of the participants met the cut-off point, which indicates that most participants had non-severe anxiety symptoms. According to Yerkes and Dodson's law, a moderate level of anxiety increases individual performance (Mellifont et al., 2016). Adolescents with such level of anxiety may manifest motivation, energy, and inspiration and devote themselves to academic activities. In summary, our findings support that anxiety can exert both positive and negative influences on academic engagement.

Furthermore, this study was the first to identify adolescent developmental differences in the link between PIU and academic engagement via depression, anxiety, and insomnia. The indirect effect of PIU on academic engagement through depression and then insomnia was stronger in middle and late adolescence than that in early adolescence, highlighting the impairments caused by PIU on mental health in later developmental stages. Additionally, learning in middle and high schools is more challenging and competitive than in elementary schools, and middle and high school students are highly expected by parents and teachers to achieve academic success (Masten et al., 2005). When their academic stress increases, adolescents who spend excessive time on the Internet and lack real-life interactions and social skills tend to become helpless, depressive, and then sleepless (Shapira et al., 2000), greatly impeding academic engagement (Pokhrel et al., 2020). Regarding the direct effect, it was stronger in early adolescence than in middle adolescence, which indicates other possible mediators between PIU and academic engagement in early adolescence, such as self-esteem (Mo et al., 2020) and social relationship (Seo et al., 2016). Also, other external (e.g., parent-child relationship) and internal factors (e.g., cognitive skills) could influence academic engagement (Zhang et al., 2019), which could be examined in future studies.

4.1. Limitations and future directions

This study advanced the knowledge on the link between PIU and academic engagement by examining the indirect effects of depression, anxiety, and insomnia and the age differences. However, certain limitations must be considered. First, this study employed a cross-sectional design that limited inferences regarding the temporal and/or causal relations among the variables (Maxwell et al., 2011). Future research should utilize a longitudinal design to better figure out the indirect effects. Also, considering the bidirectional association between PIU and depression (Yang et al., 2022), cross-lagged models examining the relations between PIU and other internalizing symptoms are needed. Second, despite its large size, the sample was fairly homogeneous in the Chinese mainland during the COVID-19 pandemic. Hence, future research should verify whether these findings also hold true in different time points during the COVID-19 and in other countries. Also, considering the long-lasting COVID-19, collecting the information about coronavirus impacts (e.g., rating the levels of how “The COVID-19 has

impacted me", from 1 "*not true of me at all*" to 5 "*very true of me*") as well as the history of mental disorders before COVID-19 are encouraged. Third, this study focused on a general population of adolescents. Considering that the associations among the study variables in the present may be different between general and clinical sample. Future research conducted in clinical sample (scoring above the cut-off value) is needed.

4.2. Implications

Despite these limitations, this study offers important implications for educational practices and psychological counseling. First, adolescents with PIU reported lower academic engagement, which raises an important question about how to improve the interest and engagement of adolescents when taking online courses, especially during the long period of COVID-19. Supervising the Internet use of adolescents is necessary, such as setting rules and regulations (Bleakley et al., 2016). Second, PIU increases the risks of depression, anxiety, and insomnia, which in turn, decreases academic engagement. This finding emphasizes the adverse effects of PIU, especially in middle and late adolescence. Therefore, interventions based on age groups for reducing PIU and psychopathological symptoms are needed. For example, the interventions for middle and late adolescents should consider both PIU behaviors and emotional regulation, such as using cognitive-behavioral and mindfulness strategies that are beneficial for reducing PIU and improving emotion regulation, learning efficiency, and academic competence (Hou et al., 2019; Mendelson et al., 2015). As for early adolescence, the interventions should focus more on Internet use and learning behaviors. Specifically, behavior-based educational programs aimed to develop healthy Internet use concepts and habits, increase academic motivation levels, and promote efficient use of time can be effective (Çelik, 2017; Uysal and Balci, 2018). Third, when controlling depression, anxiety contributed to higher academic engagement, whereas had a detrimental effect on academic engagement through insomnia. Thus, staying moderate levels of arousal/anxiety may improve academic motivations and engagement, whereas excessive anxiety may affect the sleep quality, especially in the pre-sleep period.

5. Conclusion

This study was the first to clarify the indirect effects between PIU and academic engagement across the entire span of adolescence (i.e., early, middle, late adolescence). We found that depression and subsequent insomnia, and anxiety and subsequent insomnia mediated the link between PIU and academic engagement. Meanwhile, anxiety exhibited a double-edged effect on academic engagement—positively related to academic engagement directly and negatively related to academic engagement indirectly through insomnia. Regarding the developmental differences of adolescence, the chained mediating effect of PIU on academic engagement through depression and insomnia were stronger in middle and late adolescence than in early adolescence, whereas the direct effect of PIU on academic engagement in early adolescence was stronger than that in middle adolescence, thereby highlighting the adverse consequences on depression and insomnia in middle and late adolescence. In general, these findings suggest the importance of decreasing PIU and psychopathological symptoms when improving academic engagement, which helps educators deepen the understanding on identifying and intervening students who may have poor academic engagement. Furthermore, the intervention programs should be designed for targeted age groups and must be provided at the earliest time.

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CRediT authorship contribution statement

Sihan Liu: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Shengqi Zou**: Software, Investigation, Resources, Writing - review & editing. **Di Zhang**: Software, Writing - review & editing. **Xinyi Wang**: Investigation, Resources, Data curation, Writing - review & editing. **Xinchun Wu**: Conceptualization, Project administration, Supervision.

Declaration of competing interest

None.

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