

## Insomnia partially mediated the association between problematic Internet use and depression among secondary school students in China

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**Background and aims:** This study aims to examine the mediating effects of insomnia on the associations between problematic Internet use, including Internet addiction (IA) and online social networking addiction (OSNA), and depression among adolescents. **Methods:** A total of 1,015 secondary school students from Guangzhou in China participated in a cross-sectional survey. Levels of depression, insomnia, IA, and OSNA were assessed using the Center for Epidemiological Studies–Depression Scale, Pittsburgh Sleep Quality Index, Young’s Diagnostic Questionnaire, and Online Social Networking Addiction Scale, respectively. Logistic regression models were fit to test the associations between IA, OSNA, insomnia, and depression. The mediation effects of insomnia were tested using Baron and Kenny’s strategy. **Results:** The prevalence of depression at moderate level or above (CES-D  $\geq$  21), insomnia, IA, and OSNA were 23.5%, 37.2%, 8.1%, and 25.5%, respectively. IA and OSNA were significantly associated with depression (IA: AOR = 2.79, 95% CI: 1.71, 4.55; OSNA: AOR = 3.27, 95% CI: 2.33, 4.59) and insomnia (IA: AOR = 2.83, 95% CI: 1.72, 4.65; OSNA: AOR = 2.19, 95% CI: 1.61, 2.96), after adjusting for significant background factors. Furthermore, insomnia partially mediated 60.6% of the effect of IA on depression (Sobel  $Z = 3.562$ ,  $p < .002$ ) and 44.8% of the effect of OSNA on depression (Sobel  $Z = 3.919$ ,  $p < .001$ ), respectively. **Discussion:** The high prevalence of IA and OSNA may be associated with increased risk of developing depression among adolescents, both through direct and indirect effects (via insomnia). Findings from this study indicated that it may be effective to develop and implement interventions that jointly consider the problematic Internet use, insomnia, and depression.

**Keywords:** online social networking addiction, Internet addiction, insomnia, depression, mediation

### INTRODUCTION

Globally, depression is one of the most widely reported psychiatric disorders among adolescents (Thapar, Collishaw, Potter, & Thapar, 2010). In China, the prevalence of mild, moderate, and severe depression, as assessed using Children’s Depression Inventory, was 14.6%, 15.3%, and 12.4% among middle school students, respectively (Feng & Zhang, 2005). Depression is positively associated with several negative health outcomes (e.g., substance use and suicidal behaviors) that could impact adolescents’ future development (Cairns, Yap, Pilkington, & Jorm, 2014; Thapar, Collishaw, Pine, & Thapar, 2012; Wu, Li, Lau, Mo, & Lau, 2016).

Problematic Internet use (PIU), defined as an impulse-control disorder (Shaw & Black, 2008), is a risk factor of depression among adolescents. PIU has been distinguished into a more generalized and a more specific form (Davis, 2001). Internet addiction (IA), in general, refers to individual’s overall Internet use in a compulsive way (Davis,

2001; Tsitsika et al., 2014). The high prevalence of IA has been reported among Asian adolescents, varying from 6.2% in Japan to 21.1% in the Philippines (Mak et al., 2014). In China, IA prevalence among adolescents is high 26.0% in 2011 (Chinese Internet Association of Adolescents, 2012).

Specific types of PIU has raised concerns in recent years, which refers to compulsive use of specific online functions (Davis, 2001), i.e., online social networking. The importance of investigating specific types of PIU has been highlighted in previous studies (Laconi, Tricard, & Chabrol, 2015). Online social networking addiction (OSNA), a specific type of PIU, is defined as compulsive use of online social networking (Kuss & Griffiths, 2011). Several studies reported the prevalence of OSNA among adolescents, greatly ranging from 1.6% in Nigeria (defined by 4th quartile of

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Facebook Addiction Symptoms Scale) to 34.3% in mainland China (defined by five or more “yes” answers of eight items selected from the Young’s Internet Addiction Test) (Alabi, 2013; Wolniczak et al., 2013; Zhou, 2010).

OSNA, as well as IA in general, is recent but insufficiently investigated phenomena. It is warranted to look at depression as a potential negative health outcome of both IA and OSNA among adolescents. IA and OSNA decline with adolescents’ social involvement, and then lead to increased symptoms of psychiatric disorder (i.e., depression) (Kraut et al., 1998). The positive relationship between IA and depression among adolescents has been repeatedly reported in both cross-sectional (Wu et al., 2016) and longitudinal studies (Ko et al., 2014; Lam & Peng, 2010). For instance, a 9-month longitudinal study showed that students with IA at baseline were 2.5 times more likely to develop depression than those without IA at baseline (Lam & Peng, 2010). Furthermore, adolescents with OSNA had a high level of depressive symptoms (Banyai et al., 2017). Some recent cross-sectional surveys reported a positive association between OSNA and depressive symptoms among young adults and adolescents (Koc & Gulyagci, 2013; Shensa et al., 2017).

Insomnia is another significant public health concern in adolescents. It is a heterogeneous complaint reflecting reduced quality, duration, or frequency of sleep (Tsai et al., 2005). Insomnia is significantly linked with behavioral and emotional problems among adolescents, including depression (Taylor, Lichstein, & Durrence, 2003; Xu et al., 2012). Researchers have pointed out that insomnia is a potential predictor as well as a symptom of depression (Baglioni et al., 2011). Poor sleep quality [defined by the Pittsburgh Sleep Quality Index (PSQI)] is associated with depressive symptoms among adolescents (Xu et al., 2012). A longitudinal study conducted among adolescents reported that late bedtime and short sleep duration (components of insomnia) strongly predicted development of anxiety and depression (Matamura et al., 2014). It is possible that insufficient sleep leads to fatigue and apathy at school, impaired social functioning, and impaired ability to regulate mood and emotional responses (Chorney, Detweiler, Morris, & Kuhn, 2008).

Sleep problems and PIU are common among children and adolescents. IA and OSNA compete with off-line activities including time that could be used for sleeping, and hence potentially cause insomnia. Excessive Internet use among adolescents often occurs at night (Primack, Swanier, Georgiopoulos, Land, & Fine, 2009), and adolescents with a higher IA score reported getting to bed later, requiring more time to fall asleep, and disrupting their sleep–wake schedule (i.e., increased number of awakening at night) than those with lower IA score (Ekinci, Celik, Savas, & Toros, 2014; Van den Bulck, 2004). Adolescents with OSNA are at a high risk of insomnia (Hanprathet, Manwong, Khumsri, Yingyeun, & Phanasathit, 2015). A recent study conducted among undergraduate students in Peru showed that prevalence of insomnia (PSQI score > 5) among Facebook addicts was 1.31 times higher than that among non-addicts (Wolniczak et al., 2013). However, there is a dearth of studies investigating the relationship between IA/OSNA and insomnia among adolescents, especially OSNA.

PIU (both IA and OSNA) is a potential risk factor of both adolescents’ insomnia and depression. Given the interrelationships between IA/OSNA, insomnia, and depression, it is logical to contend that insomnia could potentially mediate the relationships between PIU (i.e., IA and OSNA) and depression among adolescents. Two previous cross-sectional studies assessed the mediation effect of insomnia on the association between IA and depression among adolescents. One of them was conducted among Nepali undergraduate adolescents, reporting that insomnia mediates 30.9% effect of IA on depression (Bhandari et al., 2017), whereas another study conducted among Hong Kong adolescents reported a low mediation effect (5%) of IA on depression (Cheung & Wong, 2011). However, these two studies did not involve OSNA. A recent longitudinal study showed that 53% of the association between problematic online social networking use (as measured by four items that were adapted from the Young’s Internet Addiction Scale) and depressed mood was mediated by sleep disruptions (Vernon, Modecki, & Barber, 2017).

In this study, we aimed to investigate the prevalence of IA, OSNA, insomnia, and depression among secondary school students in Guangzhou, China. We also investigated the associations between IA/OSNA and depression, and those between IA/OSNA and insomnia, adjusted for significant background factors. We then tested the mediation effect of insomnia on the associations between IA/OSNA and depression. We hypothesized that insomnia would partially mediate the associations between IA/OSNA and depression, after adjusting for significant background factors.

## METHODS

### *Participants and procedure*

This cross-sectional survey selected two secondary schools by convenience sampling, one from an urban area and one from a rural area in Guangzhou, mainland China. The study procedure and sampling methodology has been described in detail in a previously published paper that was based on the same sample (Li et al., 2016), which validated an instrument that could be used to assess adolescents’ online social networking use intensity.

A total of 1,088 students were invited to join the study and completed the questionnaire. The data obtained from 73 participants were removed from data analysis, considering that they had more than 20% of items missing for one or more measurement scales. The remaining 1,015 questionnaires (93.3%) had only 0.11%–3.74% of missing item responses, which were imputed by mode values. The data of 1,015 participants were then analyzed in this study.

### *Measures*

*Depression.* Level of depression was assessed using the Chinese version of the 20-item Center for Epidemiological Studies-Depression scale (CES-D), which is a commonly used self-reported instrument for screening depressive symptoms. Its Chinese version of CES-D has been validated (Chen, Yang, & Li, 2009; Cheng, Yen, Ko, & Yen, 2012)

and widely used among Chinese student population (Que, Tao, He, Zhang, & Zhu, 2007; Zhang et al., 2010). Participants rated how often they experienced the symptoms such as restless sleep and feeling lonely in the previous week on a 4-point Likert scale (ranging from 0 = rarely or none of the time to 3 = almost or all of the time). The total score ranged from 0 to 60, with higher scores indicating more symptoms of depressive. In this study, the Cronbach's  $\alpha$  was .87. Students with CES-D scores between 16 and 21 were defined as "mildly depressed," 21–24 as "moderately depressed," and  $\geq 25$  as "severely depressed" (Song et al., 2008).

*Internet addiction (IA).* Internet addiction was assessed using Young's 8-item Diagnostic Questionnaire, which involved "yes/no" response categories. Participants who provided five or more "yes" answers were classified as Internet addicts (Aboujaoude, 2010; Young, 1998). The scale has been successfully used in Chinese student with acceptable psychometric properties (Fu, Chan, Wong, & Yip, 2010; Li, Zhang, Lu, Zhang, & Wang, 2014). Its Cronbach's  $\alpha$  was .73 in our sample.

*Online social networking addiction (OSNA).* Online social networking addiction was measured using an adapted version of the Facebook Addiction Scale (Koc & Gulyagci, 2013). OSNA scale included eight items by describing core addictive symptoms. Response categories rated from 1 (not true) to 5 (extremely true), with a total score ranging from 8 to 40; higher scores indicate higher levels of addictiveness to online social networking. The development and psychometric properties of OSNA have been thoroughly evaluated in our previously published paper (Cronbach's  $\alpha = .86$ ) (Li et al., 2016). There is currently no established cut-off value for defining OSNA status. Following the cut-off point strategy used in some previous studies (Alabi, 2013; Yaghjian et al., 2017), we divided the students' scores into four quartile groups, and those in the fourth quartile (i.e., OSNA score  $\geq 21$ ) were defined as having OSNA.

*Insomnia.* PSQI was used to classify insomnia over the past month. Its Chinese version has been shown to have good overall psychometric properties (Tsai et al., 2005), and been widely used in Chinese adolescents (An et al., 2014; Zhou et al., 2012). The 18-item PSQI evaluated participants' experience in seven components: sleep latency, sleep duration, habitual sleep efficiency, subjective sleep quality, use of sleep medication, sleep disturbances, and daytime dysfunction. Each component ranges from 0 (no difficulty) to 3 (severe difficulty). In this study, the Cronbach's  $\alpha$  of seven PSQI components was .62. A global score (range: 0–21) was generated by adding up these component scores, with higher scores implying poorer sleep quality. Insomnia is defined as those with PSQI global scores exceeding 5 (Tsai et al., 2005).

*Background covariates.* Background covariates that were selected in this study included sociodemographic variables (i.e., gender, school district, grade, parental education level, perceived family financial situation, and smartphone ownership) and school-related variables (i.e., self-reported academic performance and perceived study pressure).

#### Statistical analysis

Descriptive statistics (e.g. means, standard deviation, and percentages) were presented. Depression at moderate or

above level (CES-D  $\geq 21$ ) was used as the dependent variable in this study (Song et al., 2008; Wu et al., 2016). Univariate odds ratios were estimated using univariate logistic regression analysis. The associations between IA/OSNA/insomnia and depression, and those between IA/OSNA and insomnia were tested by fitting logistic regression models, adjusted for background variables with  $p < .10$  in the univariate associations. Adjusted odds ratios with corresponding 95% confidence intervals (95% CIs) were reported.

The mediating effects of insomnia for the relationships between IA/OSNA and depression were tested using a series of hierarchical logistic regression models, adjusting for significant background variables. Based on Baron and Kenny's (1986) strategy, mediation is demonstrated when (a) the independent variable (i.e., IA and OSNA) is significantly associated with the dependent variable (i.e., depression); (b) the independent variable (i.e., IA and OSNA) is significantly associated with the potential mediator (i.e., insomnia); and (c) the potential mediator is significantly associated with the dependent variable (i.e., depression) when the independent variable (i.e., IA and OSNA) is controlled for. The size of mediation effect through insomnia was evaluated by  $ab/(ab + c')$  (MacKinnon, Fairchild, & Firtz, 2008), where  $a$  is the regression coefficient between the independent variable and the mediator,  $b$  is that between the mediator and the dependent variable adjusting for the independent variable, and  $c'$  is that between the independent variable and the dependent variable adjusting for the mediator. The Sobel  $Z$  test was used to assess whether the mediation effects of insomnia for the associations between IA/OSNA and depression were statistically significant (MacKinnon et al., 2008). All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). The statistical significant level was 0.05 (two-sided).

#### Ethics

The study procedures were carried out in accordance with the Declaration of Helsinki. School consent and permission for the in-school survey were obtained from the school principals, and verbal consent was obtained from participants themselves. The study and the consent procedure were approved by the Survey and Behavioral Research Ethics Committee of the Chinese University of Hong Kong.

## RESULTS

#### Sample characteristics

Sample characteristics are presented in Table 1. Of the 1,015 students, 44.0%, 39.3%, and 16.7% were 7th, 8th, and 9th grade (i.e., 7–9 years of formal education) students, respectively; 58.8% of the participants were males. About one third (32.2%) self-reported high levels of academic pressure, and about two third (60.4%) had a smartphone.

#### Insomnia and components of PSQI

As shown in Table 1, around one fifth of the participants (20.1%) perceived poor/very poor subjective sleep quality,

Table 1. Sample characteristics (n = 1,015)

	n	%
Social-demographic variables		
Gender		
Female	418	41.2
Male	597	58.8
School district		
Urban	464	45.7
Rural	551	54.3
Grade		
Seven	447	44.0
Eight	399	39.3
Nine	169	16.7
Father's education level		
Primary school or below	157	15.5
Junior high school	510	50.3
Senior high school	234	23.1
University or above	72	7.1
Unknown	42	4.1
Mother's education level		
Primary school or below	212	20.9
Junior high school	483	47.6
Senior high school	217	21.4
University or above	56	5.5
Unknown	47	4.6
Perceived family financial situation		
Very good/good	366	36.1
Medium	609	60.0
Very poor/poor	40	3.9
Smartphone ownership		
No	402	39.6
Yes	613	60.4
School-related variables		
Academic performance		
Upper	224	22.1
Medium	565	55.7
Lower	226	22.3
Perceived study pressure		
No/little	118	11.6
General	570	56.2
Heavy/very heavy	327	32.2
PSQI components		
Subjective sleep quality		
Very good/good	811	79.9
Poor/very poor	204	20.1
Sleep duration		
>7 hr	702	69.2
5–7 hr	233	23.0
<5 hr	80	7.8
Habitual sleep efficiency		
>85%	816	80.4
65%–85%	87	8.6
<65%	112	11.0
Sleep medicine use		
No, during the last month	985	97.0
Yes, during the last month	30	3.0
Sleep latency <sup>a</sup>	0.86 ± 0.85	
Sleep disturbance <sup>a</sup>	0.93 ± 0.55	
Daytime dysfunction <sup>a</sup>	1.38 ± 0.87	
Insomnia (defined as PSQI > 5)		
No	637	62.8
Yes	378	37.2

Table 1. (Continued)

	n	%
Level of Internet use		
No Internet use	33	3.3
Non-IA	900	88.6
IA (defined as YDQ > 5)	82	8.1
Level of OSN use		
No OSN use	105	10.3
Non-OSNA	651	64.1
OSNA (defined as score in 4th quartile)	259	25.5
Depression		
No (CES-D < 16)	597	58.8
Mild (CES-D ≥ 16 and CES-D < 21)	180	17.7
Moderate (CES-D ≥ 21 and CES-D < 25)	102	10.1
Severe (CES-D ≥ 25)	136	13.4

Note. OSN: online social networking; OSNA: online social networking addiction; IA: Internet addiction; PSQI: Pittsburgh Sleep Quality Index; YDQ: Young's Diagnostic Questionnaire; CES-D: Center for Epidemiologic Studies-Depression Scale.

<sup>a</sup>Continuous variables, presented by mean ± SD.

and 30.8% slept for less than 7 hr per night. About 3.0% of the students used sleep medicine during the last month. The overall prevalence of insomnia in our sample was 37.2%.

#### Prevalence and levels of IA, OSNA, and depression

Of the 1,015 participants, 3.3% reported that they did not use the Internet, and 10.3% did not use online social networking; 8.1% were classified as Internet addicts; 25.5% were as having OSNA (defined as participants in the 4th quartile of OSNA scores, i.e., ≥21). Moreover, 28.1% of the participants had either IA or OSNA, and 5.5% of participants had both IA and OSNA. Prevalence of depression at a mild level or above (CES-D ≥ 16), moderate level or above (CES-D ≥ 21), and severe level (CES-D ≥ 25) was 41.2%, 23.5%, and 13.4%, respectively. The prevalence is presented in Table 1.

#### Associations between background variables and depression

The univariate associations between background variables and depression are presented in Table 2. All background variables associated with depression under *p* < .10 level, including school district, grade, perceived family financial situation, smartphone ownership, academic performance, and perceived study pressure, were adjusted for in the subsequent analyses for the associations between IA/OSNA and depression and between IA/OSNA and insomnia.

#### Associations between IA/OSNA and insomnia

Adjusted for the background variables that are presented in Table 2, OSNA and IA were both positively and significantly associated with insomnia (AOR = 2.19, 95% CI: 1.61, 2.96 for OSNA; AOR = 2.83, 95% CI: 1.72, 4.65 for IA; see Table 3).

Table 2. Background variables as factors of depression ( $n = 1,015$ )

	Depression		ORu (95% CI)
	<i>n</i>	%	
Social-demographic variables			
Gender			
Female	90	21.5	1
Male	148	24.8	1.20 (0.89, 1.62)
School district			
Urban	96	20.7	1
Rural	142	25.8	1.33 (0.99, 1.79) <sup>†</sup>
Grade			
Seven	79	17.7	1
Eight	103	25.8	1.62 (1.17, 2.26)**
Nine	56	33.1	2.31 (1.54, 3.45)***
Father's education level			
Primary school or below	45	15.5	1
Junior high school	116	50.3	0.73 (0.49, 1.10)
Senior high school	54	23.1	0.75 (0.47, 1.18)
University or above	16	7.1	0.71 (0.37, 1.37)
Unknown	7	4.1	0.50 (0.21, 1.20)
Mother's education level			
Primary school or below	54	20.9	1
Junior high school	115	47.6	0.91 (0.63, 1.33)
Senior high school	44	21.4	0.74 (0.47, 1.17)
University or above	14	5.5	0.98 (0.50, 1.92)
Unknown	11	4.6	0.89 (0.43, 1.88)
Perceived family financial situation			
Very good/good	70	19.1	1
Medium	155	25.5	1.44 (1.05, 1.98)*
Very poor/poor	13	32.5	2.04 (1.00, 4.15)*
Smartphone ownership			
No	75	18.7	1
Yes	163	26.6	1.58 (1.16, 2.15)**
School-related variables			
Academic performance			
Upper	40	22.4	1
Medium	126	56.5	1.32 (0.89, 1.96)
Lower	72	22.6	2.15 (1.38, 3.35)***
Perceived study pressure			
No/little	20	17.0	1
General	98	17.2	1.02 (0.60, 1.73)
Heavy/very heavy	120	36.7	2.84 (1.67, 4.83)***

Note. ORu: univariate odds ratios, obtained by univariate logistic regression models; 95% CI: 95% confidence interval.

<sup>†</sup> $p < .10$ . \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

Table 3. Associations between OSNA/IA and insomnia among adolescents ( $n = 1,015$ )

	Insomnia		ORu (95% CI)	AOR (95% CI)
	<i>n</i>	%		
OSNA				
Non-OSNA/no OSN use	238	31.5	1	1
OSNA	140	54.1	2.56 (1.92, 3.42)***	2.19 (1.61, 2.96)***
IA status				
Non-IA/no Internet use	324	34.7	1	1
IA	54	65.9	3.69 (2.27, 6.00)***	2.83 (1.72, 4.65)***

Note. ORu: univariate odds ratios, obtained by univariate logistic regression models. AOR: adjusted odds ratio, obtained by binary logistic regression after adjustment of school district, grade, perceived family financial situation, smartphone ownership, academic performance, and perceived study pressure; 95% CI: 95% confidence interval; IA: Internet addiction; OSN: online social networking; OSNA: online social networking addiction.

\*\*\* $p < .001$ .

Associations between IA/OSNA/insomnia and depression

Adjusted results showed that both IA and OSNA were significantly associated with depression (AOR = 2.79, 95% CI: 1.71, 4.55 for IA in Model 1; AOR = 3.27, 95% CI: 2.33, 4.59 for OSNA in Model 2; see Table 4). The adjusted model showed that insomnia was positively and significantly associated with depression (AOR = 3.46, 95% CI: 2.53, 4.76 in Model 3; see Table 4). When IA and OSNA were entered together into Model 4, IA and OSNA were still significantly associated with depression, but the odds ratio of IA on depression was smaller than that of OSNA on depression (AOR = 1.80, 95% CI: 1.07, 3.04 for IA; AOR = 3.12, 95% CI: 2.22, 4.40 for OSNA).

Testing insomnia as a mediator on the associations between IA/OSNA and depression

When insomnia was added to Model 1 that only contained IA, the odds ratio of IA on depression remained statistically significant but diminished from 2.79 to 2.23. Similarly, when insomnia was added to Model 2 that only contained OSNA, the odds ratio of OSNA on depression was still statistically significant but diminished from 3.27 to 2.80. The results suggested that insomnia partially mediated the associations between IA/OSNA and depression. The mediation effect sizes of insomnia were 60.6% for the association between IA and depression (Sobel  $Z = 3.562, p < .001$ ) and 44.8% for the association between OSNA and depression (Sobel  $Z = 3.919, p < .001$ ), respectively.

DISCUSSION

A high prevalence of depression at moderate or above level was observed in this study. Depression defined by a screening instrument (i.e., CES-D) was a significant predictor of clinical depression diagnosis (Pietsch et al., 2013) and other physical and psychological problems (i.e., eating disorders, substance use, and suicidal ideation and attempts) (Birmaher, Arbelaez, & Brent, 2002). As the most frequently reported mental health issue among adolescents, the high prevalence of depression signifies the need for mental health promotion among adolescents in China.

In line with previous cross-sectional and longitudinal studies (Lam & Peng, 2010; Yoo, Cho, & Cha, 2014), adolescents with IA in this study are more likely to be depressed compared with those without IA. Furthermore, OSNA has become a significant public health concern, alongside the growing popularity of online social networking among adolescents (Shi & Niu, 2010; Wang, Jackson, Gaskin, & Wang, 2014). Our findings revealed that adolescents with OSNA were 3.27 times more likely than others to be depressed. The finding was consistent with those of previous studies that reported positive association between addictive online social networking and high level of depression (Hanprathet et al., 2015; Koc & Gulyagci, 2013). Interestingly, our findings showed that when IA and OSNA were entered together into the same model, OSNA and IA have independent effects on depression but the effect of OSNA was larger than that of IA.

Table 4. Associations between Insomnia, OSNA, IA, and depression among adolescents (n = 1,015)

	Depression, n (%)	Model 1 AOR (95% CI)	Model 2 AOR (95% CI)	Model 3 AOR (95% CI)	Model 4 AOR (95% CI)	Model 5 AOR (95% CI)	Model 6 AOR (95% CI)
IA status							
Non-IA/no Internet use	197 (21.1)	1	–	–	1	1	1
IA	41 (50.0)	2.79 (1.71, 4.55)***	–	–	1.80 (1.07, 3.04)*	2.23 (1.34, 3.70)**	2.80 (1.98, 3.98)***
OSNA status							
Non-OSNA/no OSN use	126 (16.67)	–	1	–	1	1	1
OSNA	112 (43.2)	–	3.27 (2.33, 4.59)***	–	3.12 (2.22, 4.40)***	3.12 (2.22, 4.40)***	2.80 (1.98, 3.98)***
Insomniacs							
No	87 (13.7)	–	–	1	–	1	1
Yes	151 (40.0)	–	–	3.46 (2.53, 4.76)***	–	3.27 (2.38, 4.52)***	2.92 (2.08, 4.09)***

Note. All models were adjusted by school district, grade, perceived family financial situation, academic performance, perceived study pressure, and smartphone ownership. OSNA: online social networking addiction; IA: Internet addiction; OR: Odds ratio; 95% CI: 95% confidence interval; AOR: adjusted odds ratio; –: not applicable.  
\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

Interventions should hence pay attention to both specific and general aspects of PIU. As the strength of associations between OSNA and depression was stronger than that between IA and depression, the findings highlighted the importance of investigating specific types of Internet addictive behaviors, OSNA in our case (Montag et al., 2014). Evidence-based interventions on reducing OSNA are hence warranted.

Our findings further suggested that insomnia was common among secondary school students in China (37.2%). In this study, both IA and OSNA were significant risk factors of insomnia after adjusting for the significant background variables. Both IA and OSNA contributed to the high prevalence of insomnia. It is plausible that excessive Internet use/online social networking inhibits adolescents' sleeping patterns. Addicts might need more time to fall asleep and may have shorter sleep duration than non-addicts, contributing to a higher risk of insomnia (Ekinci et al., 2014; Harbard, Allen, Trinder, & Bei, 2016; Nalwa & Anand, 2003). Furthermore, excessive Internet use may significantly disturb adolescents' sleep-wake schedules, which may lead to irregular sleep patterns and insomnia (Chen & Gau, 2016; Lam, 2014). A previous study showed that the use of electronic media prior to bedtime reduced sleep duration and quality (Vernon et al., 2017). It is possible to improve adolescents' sleep quality by conducting effective interventions to reduce PIU, especially that of OSNA.

The mechanism between PIU and depression is under-researched. Life events (Yang et al., 2014), psychosocial factors (e.g., self-esteem) (Wu et al., 2016), and sleep quality (Bhandari et al., 2017) are potential mediators of the aforementioned association. We found that 61% of the relationship between IA and depression, and 45% of the relationship between OSNA and depression were mediated by insomnia, respectively. The mediation effect size of insomnia for the association between IA and depression in this study was largely higher than those reported in two previous studies (61% vs. 30.9% and 5.0%) (Bhandari et al., 2017; Cheung & Wong, 2011). The discrepancy in these studies may be partially attributed to differences in populations (i.e., undergraduate students) and/or instruments used for screening depression (i.e., 9-item Patient Health Questionnaire or 12-item General Health Questionnaire) and IA (i.e., Young's 20-item Internet Addiction Test). The actual reason is unknown and beyond the scope of this study. More studies are required to estimate the potential mediation of insomnia.

The mediation findings in this study contend that adolescent PIU, especially OSNA, would increase the risk of developing insomnia, which in turn would increase the vulnerability for depression. Thus, effective treatments for insomnia and PIU should be integrated with treatments and prevention for depression among adolescents. Special attention should be paid toward managing addictive online social networking.

This study has some limitations. First, as we relied upon self-reported data collection method, there may be reporting bias. The level of depression was measured using CES-D rather than a clinical diagnosis of depression, which was not

conducted in this study due to a limitation of resources. Second, PSQI was originally developed and validated for adults, although it has been widely applied among adolescents, its psychometric properties and suitability should be reevaluated. Moreover, insomnia status defined by PSQI in our school-based study is different from clinically diagnostic insomnia, and there may be potential misclassifications and overestimation the prevalence of insomnia. Third, although the findings suggest a plausible mechanism of how PIU may increase depressive symptoms through its negative impact on sleep quality, the nature of cross-sectional study design does not allow us to infer temporal and causal mechanisms. Cautions should be considered when interpreting the mediation effect. For instance, there might be an alternative model in which depressed mood causes insomnia, which in turn increases the risk of PIU. Longitudinal studies are needed to delineate the causal relationships of these variables and their underlying mechanisms. Fourth, caution should be given that OSNA was defined as those in the 4th quartile in the absence of an established cut-off point, even though similar definitions were used in other studies. Fifth, the sample was drawn from only two secondary schools in Guangzhou, and may not be representative of the schools in Guangzhou and other cities. Therefore, caution is required when generalizing results to other populations.

In conclusion, this study found high prevalence of depressive symptoms, PIU behaviors, and insomnia among adolescents. PIU, including IA and OSNA, has direct effects on both insomnia and depression. Furthermore, the findings suggest that a high level of PIU may increase the probability of insomnia, which may further increase the risk of depression among adolescents. Interventions jointly considering the three problems should be devised and implemented.

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