A cross-lagged study of the associations among problematic smartphone use, depressive symptoms, and suicidal ideation in chinese university students

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Abstract

The present study aimed to investigate the longitudinal and reciprocal relationships among problematic smartphone use (PSU), depressive symptoms (DS), and suicidal ideation (SI) in Chinese university students. Using a cross-lagged design, the Mobile Phone Addiction Inventory Scale, the Center for Epidemiologic Studies Depression Scale, and the Self-Rating Idea of Suicide Scale as research instruments, 194 university students completed a questionnaire four consecutive times. June of Year 1, December of Year 2, June of Year 2, and December of Year 3 of their college study. We refer to these as the Time 1 (T1), Time 2 (T2), Time 3 (T3), and Time 4 (T4) assessments, respectively. The levels of PSU and DS fluctuated significantly over time. DS at T1 was significantly predicted to influence SI at T2 ($\beta = 0.17$, $p < .05$); DS at T3 was significantly predicted by PSU and by SI at T2 (respectively, $\beta = 0.30$, $p < .05$; $\beta = 0.21$, $p < .05$); DS at T2 significantly predicted PSU at T3 ($\beta = 0.14$, $p < .05$); and DS at T3 significantly predicted SI at T4 ($\beta = 0.14$, $p < .05$) in the cross-lagged pathway. DS at T3 fully mediated the relationship between PSU at T2 and SI at T4 (indirect effect: $\beta = 0.133$, 95% CI = [0.063, 0.213]). The results suggest that there is a reciprocal relationship between PSU and DS and, furthermore, that DS plays an important mediating role between PSU and SI. Our results suggest the importance of early identification and treatment of SI. Timely reduction of PSU and improvement of DS among university students may help prevent SI.

Keywords Problematic smartphone use · Depressive symptoms · Suicidal ideation · Chinese university students · Cross-lagged study

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Introduction

According to the World Health Organization, around 703,000 individuals die by suicide each year, and many more attempt suicide (WHO, 2021). In 2019, more than 77% of all suicides occurred in low- and middle-income countries (WHO, 2021). The number of student deaths in higher education is growing annually, rising from 465 to 1998 to 3,135 in 2020 in China's institutions, a 6.7-fold increase in 22 years (Yang, 2022). Two to four times more than the suicide rate of non-college students of the same age, college students are a population at high risk for suicide (Song et al., 2015). Among college students, the prevalence of SI ranged from 9.7 to 58.3% (Crispim et al., 2021). The rate of suicidal ideations during COVID pandemic is higher than that reported in studies on general population prior to pandemic and may result in higher suicide rates in future (Farooq et al., 2021).

According to Kachur et al. (1995), the suicide process begins with the emergence of SI, is followed by the stages of planning and preparation, and concludes with suicide threats, suicide attempts, and suicide death. As an early psychological activity in suicidal behavior, SI is a powerful predictor of suicidal behavior and a major risk factor for suicidal behavior (Klonsky et al., 2016). Therefore, the complete suicidal process chain is often viewed by researchers as starting with SI. Before committing suicide, people are frequently tortured, and SI is a vital link in the psychological chain that leads to suicidal behavior (Beaton et al., 2013; Deykin & Buka, 1994). Approximately 80% of those who die by suicide have previously indicated SI in some way (Xiao, 2001). It is important to note that SI is subtle, episodic, and ubiquitous (Zhang et al., 2015). As the first link in the chain leading to suicide behavior, it is crucial to concentrate on suicidal thoughts. Research on this topic can assist identify high-risk populations and develop practical strategies for preventing and reducing the occurrence of suicidal behavior.

According to earlier research, SI among university students is linked to several factors, including stress factors: problematic internet use (PIU) /PSU (Park & Lee, 2012; Shi & Xie, 2019; Zhao et al., 2021); susceptibility factors: DS, social support, and family atmosphere (Chiang et al., 2022; Du et al., 2021; Zhao et al., 2021). According to Billieux et al. (2015), the number of young people in Asia and Europe who regularly use smartphones has increased significantly over the past ten years. Additionally, the portability and small size of smartphones allow for constant access to online (and offline) content, which could potentially lead to overuse (with constant availability being a risk factor; (Elhai et al., 2017). College students who engage in PIU/PSU are more likely to have irrational ideas, including suicidal ones (Arrivillaga et al., 2020; Sedgwick et al., 2019;

Shi & Xie, 2019). The prevalence of DS among university students was reported to have increased from 33.6 to 35.4% between 2015 and 2018 (Tang & Dai, 2018), and numerous studies have shown that DS predicts levels of SI. These factors have been more prevalent in recent years (Girard et al., 2021; Liu, 2020). However, the causes, consequences, and underlying mechanisms of SI are not entirely clear. Although some empirical studies have found that the positive relationships among PSU, DS, and SI in recent years, these studies have used a cross sectional approach (Desai et al., 2021; Rozgonjuk et al., 2021; Wang & Xu, 2011; Yeung et al., 2021; Zhao et al., 2021). To fill these gaps, the current study used a cross-lagged panel model to explore the longitudinal and bidirectional relationships among PSU, DS, and SI. Moreover, we further examined the mediating effect of DS on the relationship between PSU and SI.

Problematic smartphone use and suicidal ideation

Problematic smartphone use (PSU) refers to the excessive use of the smartphone or smartphone addiction in daily life, accompanied by dysfunction and symptoms similar to substance use disorder (Elhai et al., 2019). Given the controversy about the nature of smartphone overuse, "problematic smartphone use" might be a better term compared to "mobile phone addiction" or "smartphone addiction". Montag et al. (2015) show that in the problematic internet use (PIU) literature (i.e., not only concerning smartphones), PSU may be defined as a more specific "mobile form" compared to PIU (Kuss et al., 2018). This distinction is relevant because, unlike the more general Internet (i.e., one's computer), the small size and portability of smartphones enable constant access to online (and offline) content, potentially leading to problematic smartphone use (constant availability is a risk factor) (Elhai et al., 2017). PIU/PSU have been positively linked with suicidal ideation (Arrivillaga et al., 2020; Sedgwick et al., 2019). Previous studies also have shown that during the internet era, people are more prone to using the internet to look for information about suicide and to chat with others about it (Mok et al., 2015; Yang et al., 2021). Under the influence of PIU/PSU, adolescents can experience problems with poor social relationships and mental health (Odacı & Çelik, 2013), interpersonal psychology (poor social relationships, depressive symptoms) can predict and reveal suicidal behavior (Van Orden et al., 2010).

Although the exact cause of the connection between PSU and SI is unknown, research has found an interdependence between the two (Wang & Xu, 2011). SI can make PSU worse, university students use smartphones to prevent SI, and PSU is caused by excessive smartphone use (Zhao et al., 2021). At the same time, with the convenience and richness of information on the Internet, Internet-addicted adolescents

are more likely to obtain suicide-related information through relevant web pages and forums (Liu et al., 2017), influencing their SI through networked social contagion. However, no long-term research has examined the connection between PSU and SI, which cannot strictly determine temporal and direct relationships between these two variables. In other words, it is unclear whether university students with PSU are more likely to having SI. Therefore, the current study aimed to test the bidirectional relationships between PSU and SI using a cross-lagged panel model.

Problematic smartphone use and depressive symptoms

DS is linked to PSU (Rozgonjuk et al., 2018, 2021). The Interaction of Person–Affect–Cognition–Execution model (I-PACE) states that susceptibility traits, including personality, mental health (such as anxiety and depression), genetics, and general biology, are significant for PSU (Brand et al., 2016, 2019). The I-PACE model also assumes that susceptibility traits result in PSU (Brand et al., 2016). The intensity of DS and anxiety was linked to PSU, according to a recent literature assessment of 23 studies (Elhai et al., 2017). This association is also significant among university students (Kim et al., 2015; Zhang et al., 2020). However, the majority of these studies lack longitudinal analyses and instead employ cross-sectional approaches. In a three-year analysis of longitudinal data using auto-regressive cross-lagged models, Jun (2016) discovered a bidirectional relationship between PSU and DS. Additionally, researchers found that PSU predicts DS in university students one year later (Zhang et al., 2020). Early signs of DS have also been linked to PSU one year later (Yuan et al., 2021; Zhao et al., 2021). Hence, the current study aimed to examine the bidirectional associations between PSU and DS in Chinese university students.

Depressive symptoms and suicidal ideation

Both theoretical and empirical researches have demonstrated that DS is a significant SI risk factor (Desai et al., 2021; Yeung et al., 2021). According to the three-stage theory of suicide, SI typically results from psychological or emotional anguish (Klonsky & May, 2015). On the other hand, strong evidence from empirical investigations also backs the theory that DS contribute to SI (Desai et al., 2021; Liu, 2020). DS as a prevalent psychological adjustment issue among adolescents, might raise SI (Mullen, 2018). Researchers have discovered that DS strongly predicts the development of SI in various populations (Anastasiades et al., 2017). Further research has revealed that negative feelings (such as anxiety and despair) can effectively predict

adolescent' SI (Liu, 2020). All of this research could imply that adolescent SI is directly influenced by DS. Additionally, The "depressive cognitive triad" (Zheng et al., 2015) is the belief that depressed patients lack a basic assessment of the world around them and their future that evokes a sense of cheerfulness, a sense of dependence or support, and no hope for the future (e.g., suicidal ideation). These thoughts, in turn, can exacerbate depression (Li, 1993) it has been demonstrated that college students who report SI are more likely to experience DS (Desai et al., 2021), but no long-term research has been carried out to verify the association between SI and DS. Therefore, the current study aimed to test the bidirectional relationships between DS and SI using a cross-lagged panel model.

The mediating role of depressive symptoms

According to a literature review on the stress-susceptibility model of suicide, susceptibility and stress are rarely entirely independent of one another, and their interactions are highly complex (Gong & Li, 2012). Susceptibility variables can mediate or reduce the association between stressors and SI, It has been shown that PSU can act as a stressor for suicide (Liu, 2020; Shi & Xie, 2019), and DS as an emotional susceptibility factor (Zhou et al., 2022). The mediation effect of DS as a vulnerability factor between PSU and SI is supported by some empirical investigations. For instance, a study indicated that SI and stressful life events are related to the mediation of DS (Ma et al., 2022). Additionally, it has been demonstrated that using problem networks can both directly and indirectly predict SI by way of DS (Park & Lee, 2012). Although the causal relationships between PIU/PSU and DS and SI among university students are not yet evident, another researcher has argued that there is a correlation between these variables (Wang, 2017). Therefore, the present study innovatively investigated whether DS would mediate the link between PSU and SI using a longitudinal design.

The present study

The present four-wave longitudinal study aimed to elucidate the relationships among PSU, DS, and SI in Chinese undergraduates. Our hypotheses are:

> H1: PSU and SI have a reciprocal positive relationship over time.
> H2: PSU and DS have a reciprocal positive relationship over time.
> H3: DS and SI have a reciprocal positive relationship over time.

H4: DS has a mediating role in the association between PSU and SI over time.

Method

Participants

In total, 212 university students took part in the baseline survey. Freshman status, willingness to engage in the baseline and follow-up tests, and daily smartphone use were inclusion criteria for this study. Non-Chinese speakers and people with cognitive impairment in interpreting the questionnaire items were also excluded. For the first phase of data collection, beginning in June 2019, surveys were taken every six months, with each subject receiving RMB 20 for completing a survey during each segment. People who took part in this study and filled out all four surveys (N1 = 205, N2 = 197, N3 = 195, and N4 = 194) were included in the data set. June of Year 1, December of Year 2, June of Year 2, and December of Year 3 of their college study. We refer to these as the Time 1 (T1), Time 2 (T2), Time 3 (T3), and Time 4 (T4) assessments, respectively. Among the 194 participants, about three-fifths (59.8%) were female, 52.1% were from urban areas, 47.9% lived in a one-child family. Regarding subject of study, 43.8% majored in traditional Chinese medicine, 27.3% in oral medicine, 14.4% in anesthesia, and 14.5% in forensic.

Measures

Demographic measurements

A self-administered survey asked people about their education, gender, major, whether or not they are the only child in their family, and how long they use their phone on average each day.

Problematic smartphone use

The Mobile Phone Addiction Index Scale contains 17 questions, get adapted to measure the PSU. (Huang et al., 2014; Leung, 2008). For example, one item asked participants if they "Play with your phone when you're depressed to lift your spirits." Responses were recorded on a five-point Likert scale (1 = never, 5 = always). Higher scores indicate a greater propensity for PSU. The scale has strong validity and reliability among Chinese people. For T1, T2, T3, and T4, respectively, Cronbach's α values were 0.88, 0.91, 0.76, and 0.88.

Depressive symptoms

The Center for Epidemiologic Studies Depression Scale (CESD), developed by Radloff (1977) and revised by Chen et al. (2009), was used to assess the level of DS of individuals during the week. Among the 20 items, responses to questions 4, 8, 12, and 16 are reverse scored. Responses were recorded using a four-point scale (0 = "occasional or not occurring," 1 = "Sometimes occurring," 2 = "Frequently occurring," and 3 = "Continually occurring"). The level of DS is correlated with the score. For the current sample, Cronbach's α values were 0.92 at T1, 0.89 at T2, 0.78 at T3, and 0.95 at T4.

Suicidal ideation

The level of SI among university students was assessed using the Self-Rating Idea of Suicide Scale (SIOSS), created by (Xia et al., 2012). There are 26 items on the scale. Each positive item was coded 1 for "yes" and 0 for "no," while each negative item was coded 1 for "no" and 0 for "yes." The responses were summed such that one point was given for each "no" response and no points were given for "yes" responses. Higher scores suggest more suicidal thoughts. The data were eliminated from the study if the masking factor score was 4, suggesting that the respondent was unwilling to provide honest information. At T1, T2, T3, and T4, the scale's Cronbach's α values were 0.72, 0.71, 0.65, and 0.77, respectively.

Data analysis

The four surveys were administered in June 2019 (T1), December 2019 (T2), June 2020 (T3), and December 2020 (T4). The waves at T1 and T2 were conducted before the COVID-19 outbreak, and T3 and T4 were conducted during the pandemic. Each survey was administered in a classroom. A research assistant with two years of data collection experience informed participants that participation was voluntary and that declining would not have any negative effects. Only the researcher had access to the data, which was kept private. ID from schools were gathered for data matching. The researchers did not collect any names or other identifying information about the students. The study was approved by the Wenzhou Medical University Ethics Committee.

Descriptive and correlational analyses were performed using SPSS version 24.0. AMOS 24.0 was used to conduct the cross-lagged modeling analyses. The first step was to compare the PSU, DS, and SI scores between T1 and T4 using one-way analyses of variance (ANOVAs) with repeated measurements. The associations between PSU, DS, and SI were also examined using Pearson correlations.

Table 1 Mean, SD, and repeated-measures ANOVAs (T1, T2, T3 and T4) of all variables. ($N = 194$)

	T1	T2	T3	T4			
	M (SD)	M (SD)	M (SD)	M (SD)	F	p	Partial η2
PSU	44.68 (11.33)	46.09 (12.69)	45.79 (11.58)	47.17 (10.48)	4.362	< 0.01	0.022
DS	15.31 (9.27)	15.91 (9.98)	19.20 (6.48)	13.84 (9.63)	26.782	< 0.05	0.122
SI	3.95 (2.85)	5.88 (3.34)	5.38 (2.94)	5.40 (3.06)	35.859	< 0.01	0.149

Note: PSU = problematic smartphone use, DS = depressive symptoms, SI = suicidal ideation. M, mean; SD, standard deviation

Table 2 Pearson correlations between problematic smartphone use, depressive symptoms, and suicidal ideation at T1, T2, T3, and T4

	1	2	3	4	5	6	7	8	9	10	11
1.PSU T1	1										
2.PSU T2	0.59***	1									
3.PSU T3	0.68***	0.70***	1								
4.PSU T4	0.63***	0.63***	0.72***	1							
5.DS T1	0.45***	0.32***	0.35***	0.40***	1						
6.DS T2	0.32***	0.53***	0.28**	0.45***	0.63***	1					
7.DS T3	0.36***	0.32**	0.42***	0.39***	0.47***	0.52***	1				
8.DS T4	0.33***	0.25***	0.45***	0.46***	0.58***	0.55***	0.53***	1			
9.SI T1	0.34***	0.27***	0.35***	0.32**	0.65***	0.49***	0.39***	0.40***	1		
10.SI T2	0.28***	0.39***	0.28***	0.37***	0.48***	0.68***	0.48***	0.42***	0.60***	1	
11.SI T3	0.26***	0.30***	0.33***	0.34***	0.49***	0.49***	0.52***	0.36***	0.58***	0.67***	1
12.SI T4	0.20**	0.23**	0.27***	0.32***	0.46***	0.46***	0.45***	0.56***	0.50***	0.51***	0.58***

Note: *$p < .05$; **$p < .01$; ***$p < .001$

Third, it was determined that a cross-lagged model analysis based on structural equation modeling was appropriate for the longitudinal data analysis. This tested the directional effects of the variables estimated from the cross-lagged models of PSU, DS, and SI on each other at four time points (Finkel, 1995). The mean was used to replace missing data (less than 5% of the data set). Given the multiple testing, p-values were corrected by applying the Bonferroni correction [level of significance: p < .05; (Field 2013)]. To evaluate the models, descriptive metrics including the χ^2 goodness-of-fit statistic, the Tucker–Lewis index (TLI), comparative fit index (CFI), and root mean square error of approximation (RMSEA) were utilized. Acceptable values for CFI and TLI were 0.90 and higher, as were RMSEA values of 0.08 and below (Byrne, 2010). The level of statistical significance was 0.05($p < .05$).

Results

Preliminary analyses

We compared the characteristics of those who completed all four waves of the survey ($n = 212$) versus those who were missing from waves 2–4 ($n = 17$). There were no differences between the two groups on all variables ($p > .05$).

The Harman one-way test was used to identify any common method bias (Zhou & Long, 2004). The data from the four waves were explored using principal component analysis, with the maximum factor explanations for each wave being 20.59%, 23.40%, 26.89%, and 23.59%, respectively. All of these explanations for the most important factor were less than 40%, so there was no significant common method bias.

For the four time points (T1, T2, T3, and T4), the levels of PSU, DS, and SI are shown in Table 1. One-way repeated measures of the levels of the four outcomes were compared using ANOVA and post hoc testing, and the findings revealed significantly different levels of PSU, DS, and SI. The level of PSU at T4 (47.17) was substantially higher than at T1 and T3 (44.68 and 45.79, respectively; $p < .01$ for both), whereas T2 did not show a significant difference compared to T4 (46.09; $p > .05$). There were no significant differences among the levels of PSU at T1, T2, and T3. Compared to T1, T2, and T4 (15.31, 15.91, 13.84, respectively), DS at T3 was considerably higher (19.20; $p < .001$). There was no significant change from T1 to T2, but the values at T1 and T2 were both significantly larger than at T4 ($p < .05$ for both). SI at T2, T3, and T4 (5.88, 5.38, 5.40, respectively) were all considerably higher than at T1 (3.95; $p < .001$). The T2 measure was greater than that at T3 and T4 ($p < .05$ for both), while T3 and T4 did not differ significantly from each other ($p > .05$).

As shown in Table 2, all three variables were significantly and positively correlated across the four measurements ($p < .01$).

Model testing

A cross-lagged model was built on the correlation analysis to investigate the long-term connections among PSU, DS, and SI. The hypothetical model in Fig. 1 was created and fitted to it, and the results showed that it was a good match with the following values: χ^2 / df = 2.098, CFI = 0.988, TLI = 0.946, and RMSEA = 0.075. Indicating the stability of the variables over time, each variable at T1 was able to significantly predict its performance at T2; each variable at T2 was able to significantly predict its performance at T3; and each variable at T3 was able to significantly predict its performance at T4. DS at T1 significantly predicted SI at T2 ($\beta = 0.17$, $p < .05$); DS at T3 was significantly predicted by PSU at T2 and SI at T2 (respectively, $\beta = 0.30$, $p < .05$; $\beta = 0.21$, $p < .05$); DS at T2 significantly predicted PSU at T3 ($\beta = 0.14$, $p < .05$); and DS at T3 significantly predicted SI at T4 ($\beta = 0.14$, $p < .05$) in the cross-lagged pathway. The other paths had no statistical significance.

Test for mediating effects

Combining the aforementioned findings, it can be concluded that DS at T3 may have acted as a mediator between PSU at T2 and SI at T4 in the four time points investigated.

PROCESS was used to investigate this further. As shown in Fig. 2, the direct effect of PSU at T2 on SI at T4 was not significant (c': $\beta = 0.093$, $p > .05$), but the total effect of PSU at T2 was significant (c: $\beta = 0.226$, $p < .001$). This suggests that DS at T3 may have mediated all of the effects between PSU at T2 and SI at T4. Indirect effect a*b is significant ($\beta = 0.133$, 95% CI = [0.063, 0.213]).
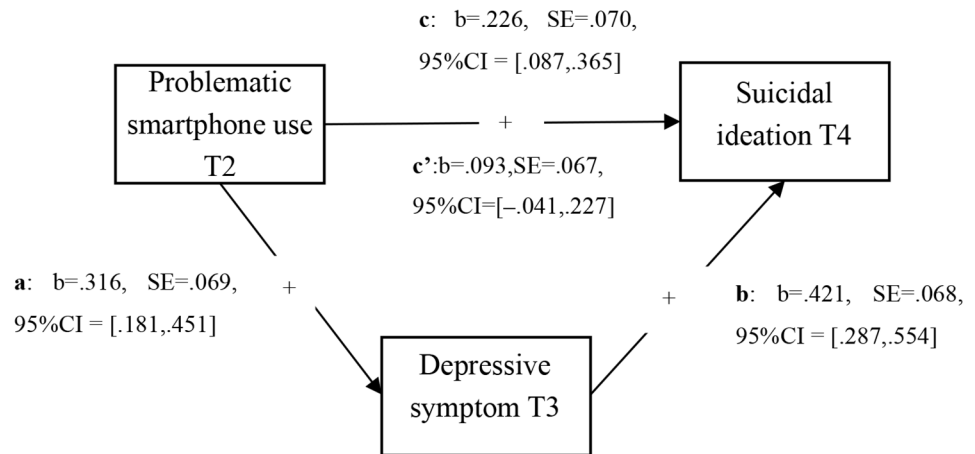
Discussion

It should be emphasized that the COVID-19 pandemic began and spread quickly around the world immediately after the second-wave survey was administered. Numerous studies have documented the detrimental effects of the pandemic on people's mental health, including an increase in stress, anxiety, and depression (Golinska et al., 2021; Mumtaz et al., 2021). However, other studies have shown that university students' mental health, including their sleep patterns and SI, improved during the pandemic (Xu et al., 2022). Therefore, it is important to consider when each wave of surveys is collected.

PSU, in particular, increased first and then declined a little, before climbing dramatically. A prior study revealed that the detection rate of mobile phone dependence among university students increased gradually as the year went on (Zhang, 2021). Between T1/T2 and T3, there was no discernible variation in the amount of PSU, which does not appear to reflect recent findings, the prevalence of PSU rose up
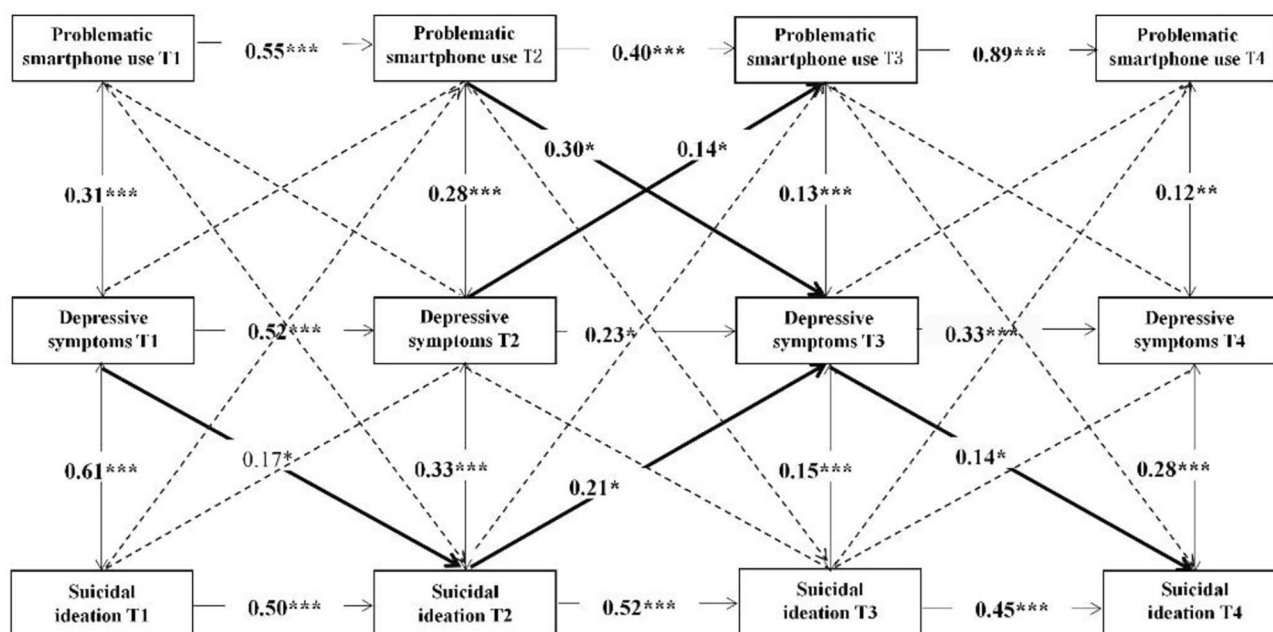
Fig. 1 Cross-lagged model of PSU, DS and SI among university students
Note3: T1, T2, T3 and T4 represent the four measurement time points

respectively, the solid path coefficients are significant standardized path coefficients, the dashed lines are non-significant paths; $N = 194$.

Fig. 2 Longitudinal mediating effects of DS in PSU and SI

c: b=.226, SE=.070, 95%CI = [.087,.365]

Problematic smartphone use T2

Suicidal ideation T4

+

c':b=.093,SE=.067, 95%CI=[−.041,.227]

a: b=.316, SE=.069, 95%CI = [.181,.451]

+

Depressive symptom T3

+

b: b=.421, SE=.068, 95%CI = [.287,.554]

than that before the COVID-19 pandemic occurred (Holmes et al., 2020; Sun et al., 2020). One plausible explanation might be that because COVID-19 isolation made PSU normal, participants may have been less likely to recognize or acknowledge withdrawal symptoms and the negative effects of smartphone use (Yang et al., 2021). Another reason could be that objectively measured smartphone use reflects the extent of PSU in some participants, who may be vulnerable for developing this condition, but not in others. In other words, while high engagement in smartphone use may be productive for some (e.g., helping with their job or school), it could be problematic for other people (e.g., leading to procrastination, decreased socializing, etc.) (Rozgonjuk et al., 2021). However, levels of PSU were noticeably greater at T4 than at T1 and T3, indicating that during the COVID-19 pandemic, participants' phone use was distinct from that during the regular school schedule. PSU may be the result of relying on smartphones to combat COVID-19-related boredom and isolation (Yang et al., 2021). Teenagers in distance education also had limited opportunities for in-person social engagement during the pandemic, which significantly increased their use of social media and messaging applications. However, excessive use of these platforms may have encouraged PSU (Marengo et al., 2022). Also, long-term, strict segregation policies are often used to keep people apart. This could lead to PSU and make it more likely that such activity will cause problems (Zhao et al., 2022).

In our study, DS gradually progressively, peaked at T3, and then sharply declining. There was no discernible difference between T1 and T2 in terms of DS levels, while T3 levels were noticeably greater than T1/T2 levels. This indicates that people were more likely to become depressed during COVID-19 than they were before the pandemic, and some studies suggest that those who may have had DS before COVID-19 are less likely to be in remission during the lockdowns (Xu et al., 2022; Yang et al., 2021). The results are in

line with claims made in several recent review papers and cross-sectional research that the COVID-19 pandemic poses a threat to people's mental health worldwide (Golinska et al., 2021; Holmes et al., 2020; Lee et al., 2021; Mumtaz et al., 2021). Additionally, studies have demonstrated that the prolonged daily use of electronic devices in addition to online learning, and feeling anxious upon returning to school are all risk factors (Yu et al., 2021). Furthermore, DS at T4 was significantly lower than during and before the pandemic, supporting previous research from Holland that indicated that DS and anxiety levels were significantly lower than they were before and during it (van der Velden et al., 2021). However, the subjects of the present study were Chinese university students who, during the later stages of the pandemic, tended to support the Chinese government's ideas and initiatives and may have led normal social lives. When students go back to school after an outbreak, they feel less lonely and "emotionally" isolated than they did during the outbreak (Yang et al., 2021).

Interestingly, SI grew significantly in this study's participants, then decreased little, and finally leveled off. University students may have rested more during the isolation period and felt less concerned about their schoolwork, which may have contributed to the huge drop in SI during the pandemic; they may also have realized the value of life and appreciated it more than before (Xu et al., 2022). According to Holmes et al. (2020), having access to up-to-date, reliable health information is linked to reduced levels of stress. By June 2020, China had effectively controlled the spread of the COVID-19 epidemic, official departments strove to improve the public's awareness of prevention (Bao et al., 2020). Contrary to our analysis, other studies have found that university students' mental health has deteriorated during the COVID-19 pandemic (Golinska et al., 2021; Lee et al., 2021). This may be the result of the fact that much of

our data were gathered after the outbreak was under control, which merits additional investigation.

According to our research, SI and PSU do not exhibit a long-term predictive relationship, contradicting H1. It appears that PSU does not directly predict SI and that SI may precede PSU. Other psychological elements may also have an impact on SI (Batterham et al., 2022). The relationship between the two might not develop quickly or might be mediated by other factors. The mediating model, on the other hand, shows that PSU at T2 predicts SI at T4 via DS at T3. These findings lend support to the stress-susceptibility hypothesis of suicide (Van Heeringen, 2001), which contends that a confluence of susceptibility and stress variables results in SI (Gong & Li, 2012). This result is also in line with earlier research that linked PIU/PSU to SI (Arrivillaga et al., 2020; Sedgwick et al., 2019).

H2 was only partially supported by the current study's findings, which showed that DS and PSU were only strongly predictive of one another at T2 and T3. Previous cross-sectional studies have demonstrated their tight link (Chen et al., 2016; Demirci et al., 2015), while longitudinal study has demonstrated their interdependent predictive relationship (Jun, 2016). Our results support the I-PACE model, which implies that DS is one of the factors contributing to PSU (Brand et al., 2016). According to some information gathered from in-depth interviews, focus groups, and studies using the pathway model, people who are depressed tend to use their smartphones excessively to lift their positive mood, suggesting that we can treat DS to lessen PSU among college students (Kim et al., 2015; Liu et al., 2022). Additionally, PSU at T2 predicted DS at T3 in this study, which is in line with earlier research (Zhang et al., 2020), as well as the idea that PSU is a stressor (Shi & Xie, 2019), a form of negative coping that may result in DS (Yang et al., 2021). However, Rozgonjuk et al. (2018) found that daily depressive mood ratings are not necessarily related to objective smartphone usage. While PSU is considered to be related to psychopathology, it could be that those who actively check their smartphones might actually exhibit better psychological well-being that could be caused by (expected) social interaction. Therefore, objective measurement should be fully considered in future research.

We discovered that SI at T1 predicted DS at T2, while DS at T3 predicted SI at T4. H3 was thus only partially supported. DS predicted the subsequent SI, but DS before the pandemic (T2) did not predict the intensity of SI during the pandemic (T3). This may be because by June 2020 (T3), China had effectively controlled the spread of the COVID-19 outbreak and the government engaged in efforts to raise public awareness about prevention techniques (Bao et al., 2020). University students are back in class and life on campus is back to normal. Following the COVID-19 outbreak,

students seem to be thinking more optimistically overall (Li et al., 2020), which could result in DS that does not foreshadow SI.

According to the results of the test for mediating effects, DS at T3 fully mediated the connection between PSU at T2 and SI at T4. H4 was thus only partially supported. The result is consistent with the stress-susceptibility model of suicide (Van Heeringen, 2001) and corroborates the prior research (Ma et al., 2022; Park & Lee, 2012). Students use mobile phones to relieve stress during university studies, especially in medical education settings, which are regarded as highly stressful and where students may encounter stressful events such as psychosocial and academic factors (Borjalilu et al., 2015). However, excessive use of mobile phones can result in PSU (Zhao et al., 2021), PSU as a form of negative coping (Kardefelt-Winther, 2014), may cause DS (Jun, 2016) and further induce SI (Mullen, 2018). The COVID-19 pandemic may have acted as an uncertainty factor that altered the model's initial results, which should be thoroughly investigated in the future. DS at other times did not function as a mediator between PSU and SI. It is also conceivable that further investigation will reveal additional crucial factors.

Limitations

Several restrictions must be recognized. First, because no data from other raters (such as peers, teachers, or family members) or behavioral or physiological aspects (such as blood pressure, heart rate, muscle activity, skin temperature, activity, and facial expressions) were collected for this study, fully capturing subjects' PSU may have been difficult, depending on how the data were analyzed. Future research should confirm these results among a larger population with a range of educational experiences. Second, despite being extensively used, the SIOSS had relatively low Cronbach's α coefficients in this study (0.72, 0.71, 0.65, and 0.77, at T1, T2, T3, and T4, respectively). Third, a modest sample size was used to estimate the structural equation model. An N:q ratio of 10:1 shows acceptability, which denotes a sample size of at least 490 according to the N:q rule (i.e., the ratio of a sample size to parameters; (Jackson, 2003; Kline, 2015). The relatively limited sample size may result in unstable parameter estimations in structural equation models. As a result, care must be taken while interpreting the findings. Future research should use larger sample sizes to validate this model. Fourth, the COVID-19 pandemic, which may have had an impact on university students' levels of PSU, DS, and SI, occurred when our third and fourth survey waves were conducted. Our findings imply that during the pandemic, SI decreased significantly while DS increased

noticeably and then decreased. These potential effects of the outbreak should be investigated in further research. Fifth, objective measures of smartphone use have not been used. Future studies should combine subjective and objective measures of smartphone use (i.e., daily minutes of phone screen time, and number of phone screen unlocks over one week)(Rozgonjuk et al., 2021; Rozgonjuk et al., 2018). Finally, although the findings of this study are theoretically sound, there is still a lack of empirical research in the areas of educational interventions and psychotherapy regarding the effectiveness of identifying and treating SI in university students. To determine if there is a link between PSU and SI, more research is needed on how to spot and treat SI in college students.

Conclusions

The results suggest that there is a reciprocal relationship between PSU and DS and, furthermore, that DS plays an important mediating role between PSU and SI. Therefore, immediate intervention should be conducted to prevent students from immersing themselves in problematic smartphone use, and at the same time reduce their level of depression and the possibility of conversion to suicidal ideation. It is necessary to conduct mental health education and life education for college students, effectively guide them to surf the Internet green, cope with depression, guide them to look at life and death correctly, and establish a scientific view of life and death. For example, implementing methods to enhance stress relaxation and adaptive stress coping skills and increasing offline social support could help reduce PSU and DS (Zhao et al., 2021). Future studies should validate these findings with larger samples and other cultures.

Declarations

Disclosure The authors declare no conflicts of interest in this work.

Date The datasets in the study are available from the corresponding author on reasonable request.

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