Problematic internet use and mental health: Moderated mediating effect of social media identity and loneliness

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Abstract

Background: To better understand the underlying mechanism of the effect of problematic internet use (PIU) on mental health, this study aims to test the mediating effect of loneliness moderated by social media identity.

Objective: This study aims to test the mediating effect of loneliness moderated by social media identity.

Methods: A cross-sectional survey was conducted on 21,292 participants using a multi-stage stratified sampling strategy from 31 provinces/regions in mainland China. A moderated mediation model was established to examine the mediating effect of loneliness on the association between PIU and mental health outcomes, moderated by social media identity.

Results: Loneliness significantly mediated the association between PIU and mental health outcomes, explaining 42.53% and 45.48% of the total effect of PIU on depression and anxiety, respectively. Social media identity significantly moderated the association between PIU and depression (?= 0.002, 95% CI: 0.001 to 0.002), between PIU and anxiety (?= 0.001, 95% CI: 0.000 to 0.002), between loneliness and depression (?= 0.010, 95% CI: 0.007 to 0.013), and between loneliness and anxiety (?= 0.007, 95% CI: 0.004 to 0.010). Higher levels of social media identity were significantly associated with lower levels of loneliness (?=-0.018, 95% CI: -0.020 to -0.016).

Conclusions: Addressing loneliness may serve as a valuable approach to mitigate the impact of PIU on mental health outcomes. However, the role of social media identity poses a significant challenge in addressing health issues linked to PIU. Clinical Trial: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (Shaanxi Institute of International Trade and Commerce, JKWH-2022-02) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

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Abstract

***Background**:* To better understand the underlying mechanism of the effect of problematic internet use (PIU) on mental health, this study aims to test the mediating effect of loneliness moderated by social media identity.

Methods: A cross-sectional questionnaire survey was conducted on 21,292 participants recruited using a multi-stage stratified sampling strategy from 31 provinces/regions in mainland China. The study assessed Problematic Internet Use (PIU), depression, anxiety, loneliness, and social media identity. Additionally, the study collected sociodemographic characteristics of the participants. A moderated mediation model was established to examine the mediating effect of loneliness on the association between PIU and mental health outcomes (depression and anxiety), moderated by social media identity.

Results: About 22.80% (n=4854) and 14.20% (n=3023) of respondents reported moderate or severe symptoms of depression and anxiety, respectively. Loneliness significantly mediated the association between PIU and mental health outcomes, explaining 42.53% and 45.48% of the total effect of PIU on depression and anxiety, respectively. Social media identity significantly moderated the association between PIU and depression (β= 0.002, 95% CI: 0.001 to 0.002), between PIU and anxiety (β= 0.001, 95% CI: 0.000 to 0.002), between loneliness and depression (β= 0.010, 95% CI: 0.007 to 0.013), and between loneliness and anxiety (β= 0.007, 95% CI: 0.004 to 0.010), but not between PIU and loneliness (β=0.000, 95% CI: -0.003 to 0.003). Higher levels of social media identity were significantly associated with lower levels of loneliness (β=-0.018, 95% CI: -0.020 to -0.016).

Conclusion: Addressing loneliness may serve as a valuable approach to mitigate the impact of PIU on mental health outcomes. However, the role of social media identity poses a significant challenge in addressing health issues linked to PIU.

Keywords: Problematic Internet use; Loneliness; Anxiety; Depression; Mediation and moderated model.

1. Background

Mental health disorders, a significant contributor to the global burden of disease, represent a major public health challenge worldwide. Over the past three decades, its burden, measured in disability-adjusted life-years (DALYs), has risen from 80.8 million in 1990 to 125.3 million in 2019, with no indication of a decrease in the foreseeable future (Collaborators, 2020). The COVID-19 pandemic has further exacerbated mental health problems, resulting in an additional 53.2 million cases of depression and 76.2 million cases of anxiety, the two most prevalent mental health disorders (Santomauro D F, 2021). Responding to the prolonged mental health impacts of COVID-19 has proven challenging due to healthcare systems that were ill-prepared (Ramyadarshni et al., 2021).

Mental health disorders are influenced by a multitude of factors (Stevens, Anaya, & Culbert, 2023), with a complex interplay between biological, psychological, social, cultural, and other elements (Richter & Dixon, 2023). The rapid advancement of technology, particularly the widespread use of the Internet, has garnered significant attention for its impact on mental health (H. M., 2018). The Internet has profoundly transformed human society, altering the way people communicate and interact (Xie et al., 2021). While Internet usage can reduce communication barriers, lower costs, enable rapid responses, and promote interpersonal bonds and social networks (Xie et al., 2021), maladaptive or excessive Internet use has been linked to adverse effects on mental health (Dahl D, 2020; Odacı & Çelik, 2013; Stepanikova, Nie, & He, 2010). Empirical evidence underscores that problematic Internet use (PIU) and Internet addiction (Dell'Osso B, 2021; Hidalgo-Fuentes S, 2023; KS, 1998; Lieberman, 2020; MM, 2014) increase the likelihood of depression, anxiety, social isolation, and even suicide (Cai Z, 2023; Haddad C, 2021; Kożybska, 2022; Lakkunarajah S, 2022; Marchant A, 2017; Peng C, 2021; Yang X, 2022).

However, the underlying mechanisms of the impact of PIU on mental health have remained unclear. Recent systematic reviews have highlighted several limitations in existing studies, such as small sample sizes, variations in study settings, and a lack of moderating or mediating analyses (Lei H, 2020; Saadati HM, 2021). One assumption regarding the link between PIU and mental health disorders is that PIU is inherently connected to loneliness (T. Moretta & Buodo, 2020). Although loneliness is not a specific mental health condition, it is associated with major mental health disorders, including depression and anxiety. The role of Internet use in loneliness remains a subject of debate. Some researchers contend that Internet use can exacerbate loneliness by compromising offline human interactions (Kaess, 2014; Romer, 2013), while others argue that it can enhance existing offline relationships and foster new ones (Valkenburg & Peter, 2007). Nonetheless, the association between PIU and loneliness is likely to be bi-directional: PIU can be both a cause (resulting in higher levels of loneliness) and a consequence of loneliness (T. Moretta & Buodo, 2020).

What has been missing in these discussions is the consideration of individual behaviors: why and how individuals use the Internet. The emergence of social media has created a virtual space for people to interact, but the purposes for which people use social media can vary significantly. Online platforms can serve as tools for sharing information and exchanging social support in the real world (Chen & Wang, 2021; Ganda, 2014). This underscores the importance of the concept of social media identity (Brenden, 2022; Markus Kaakinen, 2020). According to the identity bubble reinforcement model (IBRM) (Keipi, Näsi, Oksanen, & Räsänen, 2016), online interactions can lead to the formation of social networks (social identity) where like-minded individuals (homophily) interact with one another, often relying on biased information. Social media identity measures how

people perceive their relationships within online networks, with a higher level of social media identity indicating greater involvement with online social networks (M. Kaakinen, Sirola, Savolainen, & Oksanen, 2020). It is reasonable to assume that high levels of social media identity may reinforce a sense of belonging to virtual communities at the potential expense of real-world connections (Markus Kaakinen, 2020). This, in turn, could affect the association between PIU and loneliness, as well as the impact of PIU on mental health (Betul Keles, 2020; Savolainen, 2020).

To gain a better understanding of the underlying mechanisms of the impact of PIU on mental health, this study seeks to examine the mediating effect of loneliness moderated by social media identity. While previous research has explored the influence of social media identity on online gaming and cyberbullying (Oksanen A, 2020; Savolainen, 2020), there is a noticeable gap in the literature regarding the role of social media identity in the context of PIU, loneliness, and mental health. It is worth noting that this study was conducted in China, where Asian countries have reported a higher prevalence of PIU, ranging from 20% to 47%, compared to other regions (Chia D, 2020; Hans-Jürgen Rumpf, 2022).

2. Theoretical hypothesis

In this study, we tested a moderated mediation model based on four hypotheses, examining the interplay between PIU, loneliness, social media identity, and their effects on mental health (Figure 1).

(Figure 1 near here)

2.1 PIU is positively associated with mental health disorders (H1)

The link between PIU and mental health has been extensively documented (Cai Z, 2023; Haddad C, 2021; Kożybska, 2022; Lakkunarajah S, 2022; Park S, 2013). A recent systematic review has found moderate-level evidence supporting a positive association between PIU and depressive symptoms (Cai Z, 2023). In general, PIU is associated with a withdrawal from real-world social interactions (Aiman El Asam, 2019). Excessive Internet use can also result in sleep deprivation, unrealistic expectations, and an exaggerated sense of failure (Aiman El Asam, 2019; LT., 2014).

2.2 PIU is positively associated with loneliness (H2)

PIU can lead to displacement, a phenomenon in which Internet-based, low-quality relationships replace offline social contacts, even though the Internet itself can strengthen an individual's connectedness with others and expand their social networks (T. Moretta, Buodo, G, 2020). Recent reviews have indicated moderately low levels of evidence supporting PIU as a risk factor for loneliness (T. Moretta, Buodo, G, 2020). Several longitudinal studies have shown that PIU is more likely to be a cause rather than a consequence of loneliness (Tian et al., 2018; Yao & Zhong, 2014; Zhang et al., 2018). Excessive internet use can lead individuals to withdraw from real-world interactions, intensifying their perception of the absence of companionship (Lewis G, 2017; T. Moretta, Buodo, G, 2020).

2.3 Loneliness is positively associated with mental health disorders (H3)

Existing evidence has consistently shown that loneliness is a risk factor for mental health disorders, particularly depression and anxiety. Loneliness has negative effects on social, cognitive, and biological aspects (Hawkley LC, 2010; Lee SL, 2021). Individuals experiencing loneliness often have lower levels of cognitive stimulation, reduced social interactions, and impaired immune functions, all of which are associated with an

increased likelihood of mental health disorders (Hawkley LC, 2010; Lee SL, 2021). This connection between loneliness and mental health disorders has been demonstrated in two large longitudinal studies conducted in the UK and the Netherlands (Cacioppo, 2006; Lee SL, 2021; Steen OD, 2022). In the present study, we conceptualized loneliness as a mediator in the association between PIU and mental health disorders.

2.4 Social media identity moderates the effects of PIU on loneliness and mental health disorders (H4)

Several studies have examined the role of social media identity in relation to loneliness and mental health. On one hand, social media identity is considered beneficial for individuals, as higher involvement with online social networks offers increased opportunities for self-expression and peer support, which can help reduce loneliness and mitigate the transformation of loneliness into mental health problems (Leonard Reinecke, 2014; G. M., 2014; van Schalkwyk GI, 2017), even when the online activities themselves might be harmful, as seen in cases like online gambling (Savolainen, 2020). On the other hand, individuals with a higher level of social media identity have been found to have decreased offline social interactions and an increased prevalence of mental health problems (Betul Keles, 2020; Cataldo I, 2021). In this study, we conceptualized social media identity as a moderator in the associations between PIU, loneliness, and mental health disorders.

3. Materials and Methods

3.1 Study design and participants

The data for this study were extracted from the 2022 nationwide cross-sectional survey, known as the Psychology and Behavior Investigation of Chinese Residents (PBICR-2022). To select study participants for the PBICR-2022, a multi-stage stratified quota sampling strategy was employed. The allocation of quotas took into account the demographic distributions recorded in the seventh national census, considering both age and gender, within each locality. A total of 780 residential communities were selected from 202 districts/counties spanning all 31 provinces/regions in mainland China for the PBICR-2022. Eligibility criteria for participation in the survey included individuals aged 12 years or older who had resided in the sampled communities and had not been absent for more than one month within the past year.

Data collection took place between June 20 and August 31, 2022, during a period when China was still implementing a zero-COVID policy. Household visits were carried out by trained investigators whenever local policies permitted such visits. Otherwise, online meetings, typically using platforms like WeChat or Tencent, were conducted with each participant. Respondents were asked to provide their responses through the questionnaire platform Wenjuanxing (www.wjx.com). Written informed consent was obtained prior to each survey.

A total of 30,505 responses were returned and 21,292 (69.80%) were deemed valid. The invalid responses were either incomplete or inconsistent across answers, or took less than four minutes (a minimal time required to go through all of the questions).

Details about the protocol of the PBICR-2022 survey have been published elsewhere (Wang YJ, 2022). The protocol obtained ethics approval from the Shaanxi Institute of International Trade and Commerce (JKWH-2022-02).

3.2 Measurements

3.2.1 Problematic internet use (PIU)

PIU was assessed using the Problematic Internet Use Questionnaire-Short Form-6 (PIUQ-SF-6). This

questionnaire evaluates one's obsession, neglect, and control behaviors related to internet usage. For example, respondents were asked about their feelings of tension, irritation, or stress when unable to use the internet as long as they wished, their preference for spending time online over sleep, and their attempts to conceal the amount of time spent online (Demetrovics Z, 2016; Tolulope Opakunle, 2020). Participants were required to rate each item on a five-point Likert scale, ranging from 0 (Never) to 4 (Always). A summed score within the range of 0 to 24 was calculated, with a higher score indicating a higher risk of PIU. The PIUQ-SF-6 has demonstrated good reliability and validity in several countries (Demetrovics Z, 2016; Tolulope Opakunle, 2020) and its structural validity (via confirmatory factor analysis) and internal consistency (Cronbach's alpha=0.932) was confirmed in the current.

3.2.2 Loneliness

Loneliness was assessed using the Three-Item Loneliness Scale (TILS), which evaluates relational connectedness, social connectedness, and self-perceived isolation (Hughes, 2004). Each item was rated on a 3-point scale, with 0 indicating 'hardly ever,' 1 indicating 'some of the time,' and 2 indicating 'often.' A summed score within the range of 0 to 6 was calculated, where a higher score indicated a higher level of loneliness. The TILS has been reported to have good reliability and validity in previous studies (Czerwiński, 2023; Trucharte A, 2023) and in the current study, with a Cronbach's alpha coefficient of 0.862.

3.3.3 Social media identity

Social media identity was assessed using the Identity Bubble Reinforcement Scale (IBRS) (Markus Kaakinen, 2020). The IBRS evaluates the extent to which individuals relate themselves to online social networks and consists of six items. These items measure social identification (e.g., 'In social media, I belong to a community or communities that I'm proud of'), homophily (e.g., 'In social media, I prefer interacting with people who are like me'), and information bias (e.g., 'In social media, I feel that people think like me') (Markus Kaakinen, 2020). Respondents were required to rate each item on a scale ranging from 0 (does not describe me at all) to 9 (describes me completely). A summed score within the range of 0 to 54 was calculated, with a higher score indicating a higher level of social media identity involvement. The IBRS has shown good reliability and validity in various countries (Markus Kaakinen, 2020) and in this study, yielding a Cronbach's alpha coefficient of 0.924.

3.2.4 Mental health disorders

The PBICR-2022 survey included assessments of depression and anxiety, which are among the most common mental health disorders. To measure depression, the Patient Health Questionnaire (PHQ-9) was utilized, while the General Anxiety Disorder (GAD-7) scale was adopted for assessing anxiety. Respondents were asked to rate their experiences over the past two weeks using a four-point scale, with responses ranging from 0 (not at all) to 3 (nearly every day). Sample questions included 'How often do I have trouble concentrating on things' for depression (Löwe B, 2004) and 'How often do I feel afraid that something awful might happen' for anxiety (Spitzer R L, 2006). A summed score for depression, ranging from 0 to 27, and for anxiety, ranging from 0 to 21, was calculated. A higher score indicates a higher level of symptoms. Both the PHQ-9 and GAD-7 have been widely used in various settings and have been validated in Chinese populations (He X, 2010; Ye X, BMJ Open).

3.2.5 Covariates

Previous studies have identified numerous socio-economic and demographic factors associated with mental health disorders (Anderson, Steen, & Stavropoulos, 2017; Dahlberg, McKee, Frank, & Naseer, 2022; Kong et al.,

2023). Of these factors, data regarding age group (<18, ≥18 & <30 and etc.), gender (male, female), educational attainment (no formal education, primary school, etc.), employment (full-time students, employed, freelancer and etc.), marital status (unmarried, married, divorce/widowed), household income (≤1000 Yuan, >1000 & ≤2000 Yuan and etc.), chronic conditions (yes, no), living area (rural, urban), and region were collected based on self-report. The regions were categorized into north (Beijing, Tianjin, etc.), northeast (Liaoning, Jilin, Heilongjiang), northwest (Gansu, Qinghai, etc.), eastern (Shanghai, Jiangsu, etc.), central (Henan, Hubei, Hunan), south (Guangdong, Guangxi, Hainan), southwest (Chongqing, Sichuan, etc.) according the classification of regional economic collaboration of provinces in China (Zaixing, 1995).

3.3 Statistical analysis

The characteristics of study participants were described through frequencies distributions for categorical variables and means (medians) and standard deviations (IQR: interquartile range) for continuous variables.

Wilcoxon rank sum tests and Kruskal-Wallis tests were performed to assess differences in PIU, loneliness, social media identity, and mental health disorders among those with various characteristics. Spearman correlations were examined among those measurements.

We employed multivariate linear regression models to test our hypotheses. For the moderated mediation analyses, we utilized the PROCESS macro developed by Hayes (A.F. Hayes, 2013). The analysis proceeded in two steps. First, we tested the mediation effect of loneliness on the association between PIU and depression and anxiety disorders. Following that, we added the moderation effect of social media identity on different paths within the mediation model. To estimate the indirect effects, we used 5000 bootstrap estimates, which provided a 95% bias-corrected confidence interval (CI) with robustness to non-normally distributed data. Additionally, we calculated conditional effects of social media identity by examining the associations of all paths between PIU and mental health when the social media identity score was fixed at one standard deviation above and below the mean (Andrew F. Hayes, 2013).

We conducted subgroup analyses based on gender and age to assess model robustness and identify potential model heterogeneity. As the cross-sectional data did not allow us to establish the temporal precedence of variables, we also examined a model in which PIU served as a mediator for the association between loneliness and mental health disorders. To address the potential threat of common method variance in cross-sectional behavioral research, we performed Harman's one-factor analysis. The results indicated that the first common factor in our data explained only 27.99% of the variance, which is below the threshold of 40%. This suggests a low risk of common method variance(Liu, Xiao, Kamper-DeMarco, & Fu, 2023).

Data were analyzed using SPSS 26.0 (IBM Corp.). A two-tailed p-value <0.05 was considered statistically significant. The indirect effects of the mediation and moderation variables were considered statistically significant when zero was not included between the lower and upper bound of the 95% bias-corrected bootstrap confidence intervals.

3. Results

3.1 Characteristics of study participants

Approximately half (49.77%) of the respondents were male, while 18.1% were older than 60 years. Less than one third (30.35%) resided in rural communities. The majority of respondents had completed senior high school

and above education (69%), with an average household income of less than 5000 Yuan (equivalent to approximately US $685.50), accounting for 63.02% (Table S1).

3.2 Problematic internet use, loneliness, social media identity, and mental health

The respondents had a mean score of 6.49 (SD=5.51) for depression symptoms and 4.75 (SD=4.62) for anxiety symptoms. Female respondents (p=0.003) reported more anxiety problems, while there was no gender difference in depression symptoms (p=0.068). Respondents in the age group between 18 and 29 years (p<0.001), those who were unmarried (p<0.001), had completed postgraduate education (p<0.001), were engaged in full-time studies (p<0.001), had a household income of less than 1000 Yuan per month (equivalent to approximately $137.1, p<0.001), resided in rural areas (p<0.001) and the northeastern region (p<0.001), and had chronic conditions (p<0.001) had the highest scores for both depression and anxiety (Table S2).

The loneliness scores were relatively low, with a mean value of 1.57 (SD=1.61) out of a maximum score of 6. In general, respondents with the highest anxiety and depression scores tended to also have higher loneliness scores (Table S2).

The average PIU score was 5.80 (SD=5.46) out of a maximum of 24, indicating a moderate level of problematic internet use. Respondents reported a moderate level of involvement in social media identity, with a mean score of 31.12 (SD=10.99) out of a maximum of 54. The highest levels of PIU and social media identity were found among respondents aged between 18 to 29 years (p<0.001), those who were unmarried (p<0.001), had completed postgraduate education (p<0.001), were engaged in full-time studies (p<0.001), had an average household income of more than 6000 Yuan per month (p<0.001), lived in urban areas (p<0.01), and had no chronic conditions (p<0.001). Respondents residing in the northeast region exhibited the highest PIU (p<0.001), while those in the northern region had the highest social media identity (p<0.001). There was no gender difference in PIU (p=0.101), but male respondents reported higher social media identity (p=0.040) than their female counterparts (Table S2).

PIU, loneliness, depression, and anxiety symptoms showed positive correlations with each other (p<0.001), while social media identity exhibited negative correlations with loneliness, depression, and anxiety symptoms (p<0.001) (Table 1).

Table 1. Spearman correlations of the measured construct (n=21,292)

Variables Mean ± SD[#] Median (IQR[##])	1	2	3	4	5
1 Depression 6.49 ± 5.51 6 (2-9)	1				

2 Anxiety	4.75 ± 4.62 4 (0-7)	0.811***	1							
3 Loneliness	1.57 ± 1.61 1 (0-3)	0.628***	0.622***	1						
4 Problematic internet use	5.80 ± 5.46 11 (0-10)	0.449***	0431***	0.395***	1					
5 Social media identity	31.12 ± 10.99 37 (24-38)	-0.125***	-0.105***	-0.156***	0.007	1				

#: SD: Standard Deviation; ##IQR: Inter Quartile Range *: p<0.05; **: p<0.01; ***: p<0.001.

3.2 Hypothesis testing

PIU was found to be associated with loneliness (Model 1 in Table 2), depression (Model 2), and anxiety (Model 3 in Table 2). This supports Hypotheses 1 and 2. Loneliness played a significant mediating role in these associations, as shown in Model 2 and Model 3 in Table 2. The change in R^2 values confirmed the substantial contribution of loneliness as a mediator in the relationships between PIU and depression (R^2 increased from 0.246 to 0.454) and anxiety (R^2 increased from 0.223 to 0.446).

The total effect of PIU on depression was 0.475 (95% CI: 0.462 to 0.487), of which 42.53% (0.202, 95% CI: 0.193 to 0.211) was explained by the indirect effect mediated through loneliness. Similarly, the total effect of PIU on anxiety was 0.387 (95% CI: 0.377 to 0.398), with 45.48% (0.176, 95% CI: 0.168 to 0.184) being explained by the indirect effect mediated through loneliness (see Figure 2). This supports Hypothesis 3.

(Figure 2 near here)

Social media identity moderated the effect of PIU on depression (β= 0.002, 95% CI: 0.001 to 0.002) and the effect of loneliness on depression (β= 0.010, 95% CI: 0.007 to 0.013). Similarly, social media identity moderated the effect of PIU on anxiety (β= 0.001, 95% CI: 0.000 to 0.002) and the effect of loneliness on anxiety (β= 0.007, 95% CI: 0.004 to 0.010). Higher levels of social media identity exacerbated the effects of PIU on mental health problems, supporting Hypothesis 4. However, the moderation effect of social media identity on the association between PIU and loneliness was statistically insignificant (β= 0.000, 95% CI: -0.003 to 0.003), despite the direct association between higher levels of social media identity and lower levels of loneliness (β=-0.018, 95% CI: -0.020 to -0.016).

(Table 2 near here)

Figure 3 and Figure 4 present the conditional effects of social media identity on the paths between PIU and mental health symptoms.

(Figure 3 near here)

(Figure 4 near here)

The effect of PIU on depression, including the indirect effect via loneliness, was significantly stronger among respondents with a higher social media identity compared to those with a lower social media identity. This difference manifested as a 0.032 variation in the direct effect and a

0.025 difference in the indirect effect, with a bootstrapped 95% confidence interval of 0.005 to 0.044. Similarly, the effect of PIU on anxiety, including the indirect effect via loneliness, was significantly more pronounced among respondents with a higher social media identity compared to those with a lower social media identity. This difference amounted to a 0.017 variation in the direct effect and a 0.017 difference in the indirect effect, with a bootstrapped 95% confidence interval of 0.000 to 0.033 (Table 3)

(Table 3 near here)

The subgroup analyses based on gender and age confirmed the moderated mediation models tested in this current study (Table S4). In all subgroups, except for those aged over 60 years, the indirect effects of PIU on depression and anxiety via loneliness exceeded 40% of the total effect. Additionally, higher levels of social media identity were associated with greater impacts of PIU on depression and anxiety in nearly all subgroups, with the exception of the group aged from 50 to 59 years, where this effect was not observed for the impact of PIU on depression.

The alternative model testing revealed that PIU mediated the effects of loneliness on depression and anxiety (Table S5 and S6). However, the indirect effect only explained 16.12% and 14.66% of the total effect of loneliness on depression and anxiety, respectively. The change in R^2 values also indicated a limited contribution of PIU as a mediator.

Table 2 Results of the mediation model and moderated mediation model

	Mediation model						Moderated mediation model					
Predictors	**Model 1 (Y=Loneliness)**		**Model 2 (Y=PHQ)**		**Model 3 (Y=GAD)**		**Model 4 (Y=Loneliness)**		**Model 5 (Y=PHQ)**		**Model 6 (Y=GAD)**	
	β	**95%CI**	**β**	**95%CI**	**β**	**95%CI**	**β**	**95%CI**	**β**	**95%CI**	**β**	**95%CI**
PIU	0.116	(0.112, 0.120)	0.272	(0.261, 0.284)	0.212	(0.202, 0.222)	0.117	(0113, 0.121)	0.267	(0.255, 0.279)	0.207	(0.198, 0.217)
Loneliness			1.743	(1.705, 1.781)	1.514	(1.482, 1.546)			1.739	(1.700, 1.778)	1.516	(1.484, 1.549)
Social media identity							-0.018	(-0.020, -0.016)	(0.005)	(-0.001, 0.001)	0.002	(-0.002, 0.007)
Social media identity × PIU							0.000	(-0.003, 0.003)	0.002	(0.001, 0.002)	0.001	(0.000, 0.002)
Social media identity × Loneliness									0.010	(0.007, 0.013)	0.007	(0.004, 0.010)
F	160.675		519.443		502.896		165.462		481.285		464.138	
R^2	0.200		0.454		0.446		0.214		0.456		0.447	

Table 3 Conditional indirect and direct effects of social media identity

Social media identity	Indirect effect	Boot SE	Boot LLCI	Boot ULCI	Direct effect	LLCI	ULCI
Depression							
Average	0.203	0.005	0.178	0.212	0.267	0.255	0.279
Low (Mean - 1SD)	0.190	0.006	0.178	0.203	0.251	0.234	0.268
High (Mean + 1SD)	0.216	0.007	0.201	0.229	0.283	0.268	0.298
Difference	0.025	0.010	0.005	0.044	0.032		
Anxiety							
Average	0.177	0.004	0.169	0.185	0.207	0.198	0.217
Low (Mean - 1SD)	0.169	0.006	0.158	0.180	0.199	0.185	0.213
High (Mean + 1SD)	0.185	0.006	0.174	0.197	0.216	0.204	0.229
Difference	0.017	0.008	0.000	0.033	0.017		

4. Discussion

4.1 Main findings

The study reveals that higher PIU is linked to elevated depression and anxiety symptoms. Loneliness acts as a mediator in this association, accounting for almost half of the total effects. Notably, while higher social media identity may decrease loneliness, it intensifies the impacts of loneliness and PIU on depression and anxiety.

4.2 Comparisons to the existing evidence

The study confirms a significant effect of PIU on loneliness, although the direction of the relationship remains inconclusive. This aligns with the findings of most existing studies (Alheneidi H, 2021; J., 2001; T. Moretta, Buodo, G, 2020), indicating an 'Internet displacement effect' where the Internet replaces offline interactions rather than a 'stimulation effect' where the Internet enhances existing relationships (T. Moretta, Buodo, G, 2020).

Previous studies have extensively documented the positive associations of PIU with depression and anxiety (Cai Z, 2023; Fang, Tian, Wang, & Wang, 2023; Haddad C, 2021; Kożybska, 2022; Lakkunarajah S, 2022; Park S, 2013), as well as the positive associations of loneliness with depression and anxiety (Beutel ME, 2019; Cacioppo JT, 2010; Domènech-Abella J, 2019; Luo Y, 2012). These associations were confirmed in the present study.

In our study, we discovered that loneliness serves as a significant mediator in the link between PIU and mental health disorders, explaining nearly half of the total effects on both depression and anxiety symptoms. It is worth noting that loneliness can be improved through the enhancement of social skills and the strengthening of social support (Pearce et al., 2021), providing a novel approach to mitigating the negative consequences of PIU on mental health (Santini, 2015). However, substantial direct effects of PIU on depression and anxiety symptoms remain and warrant further exploration. Existing evidence has suggested that sleep disturbance may be a potential pathway through which PIU affects mental health (Guo et al., 2018; Wang et al., 2021). Consequently, future research is needed to deepen our understanding of the underlying mechanisms in the association between PIU and mental health.

Social media has brought about revolutionary changes in people's daily lives, with profound impacts on their health. Previous studies have established connections between PIU and social media identity (Markus Kaakinen, 2020), as well as between social media identity and loneliness

(Leonard Reinecke, 2014; G. M., 2014; van Schalkwyk GI, 2017). This current study expands our existing knowledge by exploring the role of social media identity in the effects of PIU on both loneliness and mental health disorders. We found that higher levels of social media identity exacerbate the effects of PIU on mental health disorders. Social media identity is formed as individuals seek connections with like-minded others online (Markus Kaakinen, 2020; Ridings, 2004), which can reduce feelings of loneliness, as indicated in this study and others (Bu, 2020; Kamalpour, 2020; Rita Latikka, 2022). However, this reduction in loneliness does not appear to be strong enough to counterbalance the exacerbating effects of social media identity on the association between PIU and mental health disorders. One plausible explanation is that individuals with high levels of social media identity become deeply engrossed in the virtual online space at the expense of offline social interactions (M. Kaakinen, Keipi, T., Oksanen, A., et al., 2018; Koivula, 2019). This may result in a reduced ability to obtain social support from traditional relationships such as family members, friends, and work colleagues. Online relationships are often criticized for being superficial and lacking authenticity, and they cannot fully replace the role of offline relationships (Mesch & Talmud, 2006). People with a high level of social media identity may feel less lonely but have limited access to offline interactions and social support, thereby increasing their risk of depression and anxiety (Markus Kaakinen, 2020; Oksanen A, 2020).

While the primary focus of this study wasn't on the prevalence of depression and anxiety, it's noteworthy that our study participants appear to exhibit similar levels of depression and anxiety symptoms as those reported in another national study conducted in 2021 (Wang D, 2023). In our study, approximately 22.80% (n=4854) and 14.20% (n=3023) of respondents were identified as experiencing moderate or severe depression and anxiety, respectively, with scores exceeding 10 (Kroenke K, 2001; Terlizzi EP, 2020). Consistent with previous studies conducted during the COVID-19 pandemic (Santomauro D F, 2021), our research also identified female gender and young age groups, such as those between 18-29 years, as significant risk factors for mental health disorders. Recent studies have revealed a rapid increase in PIU, which is most prevalent among males and younger age groups (Endomba et al., 2022; Karacic & Oreskovic, 2017). However, our study suggests that the effects of PIU on mental health disorders are similar between male and female respondents.

4.3 Policy implications

As loneliness emerges as a significant mediator in the link between PIU and depression and anxiety, policymakers may find it beneficial to consider comprehensive strategies that address both PIU and loneliness to mitigate the negative mental health outcomes associated with PIU. China has introduced multi-level approaches targeting internet users, online content, and the internet industry to address this challenge (Administration, 2021). For instance, gaming companies have been required to impose restrictions, such as limiting young users to one hour of play during Fridays and weekends. Research indicates that intervention programs focused on specific online risks, such as gambling, cyberbullying, and online gaming, tend to be more effective than general PIU interventions (Jing Shi, 2022). Offline strategies that enhance social connectedness and social support have also demonstrated their effectiveness in reducing loneliness (Masi CM, 2011), and can be incorporated into PIU management efforts.

Social media identity plays a pivotal role in amplifying the mental health consequences of PIU, even though it is negatively associated with loneliness. This underscores the importance of helping individuals strike a balance between their online and offline relationships. While online connections can offer temporary relief from loneliness, they should not substitute or jeopardize the value of real-world connections. Potential intervention strategies may involve public education campaigns to raise awareness and encourage responsible online behavior, as well as strengthening offline social activities to promote face-to-face interactions and social support.

4.4 Strength and limitations

To our best knowledge, this is the first study of its kind to provides valuable insights into the intricate connections among PIU, loneliness, social media identity, and mental health disorders using moderated mediation modeling. The sample size was large.

There are several limitations in the current study. One significant limitation is the cross-sectional design, which prevents us from verifying the bidirectional relationship between PIU and loneliness. Future research endeavors could benefit from a longitudinal design to explore the dynamic interplay between PIU, loneliness, and mental health over time. Additionally, it is worth acknowledging that there may be other unexamined factors and pathways that contribute to the relationship between PIU and mental health. For example, variables related to sleep patterns and sedentary lifestyles could play a role in both PIU and mental health disorders (Wright, Heiman, &

Olenik-Shemesh, 2021). These factors were not included in our study due to data unavailability.

5. Conclusions

PIU is linked to symptoms of depression and anxiety, and our research has underscored the crucial role of loneliness as a mediator in this association. Loneliness is responsible for nearly half of the total effects of PIU on depression and anxiety symptoms. Intriguingly, while social media identity may offer some relief from loneliness, it paradoxically exacerbates the impact of PIU on depression and anxiety. In light of these findings, a comprehensive and multifaceted approach to PIU management is warranted, encompassing both online and offline interventions.

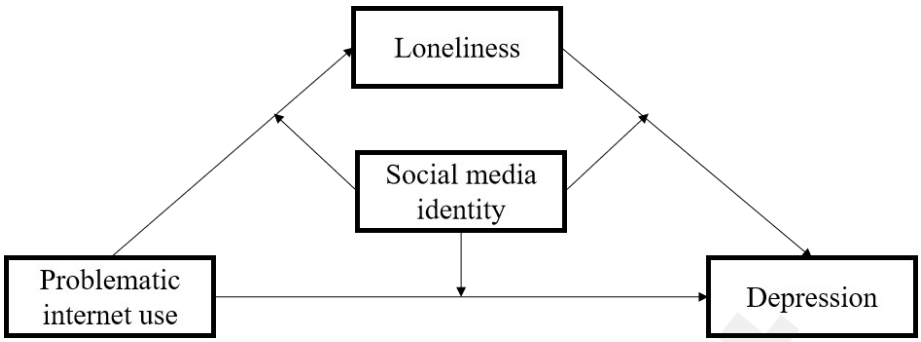

Figure 1. The hypothesized moderated mediation model

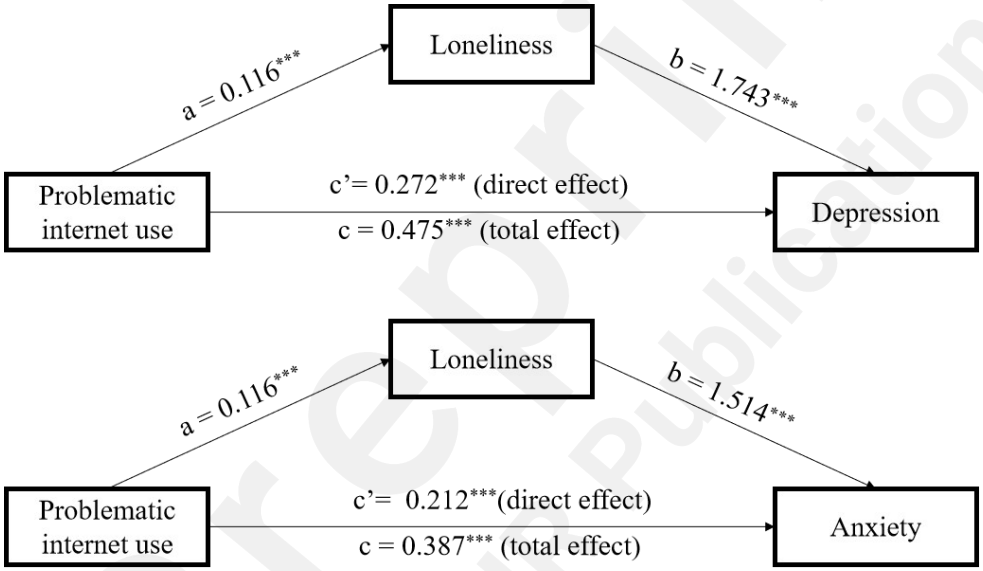

Figure 2. Mediating model of problematic internet use on depression and anxiety via loneliness.

* p < 0.05, ** p < 0.01, *** p < 0.001.

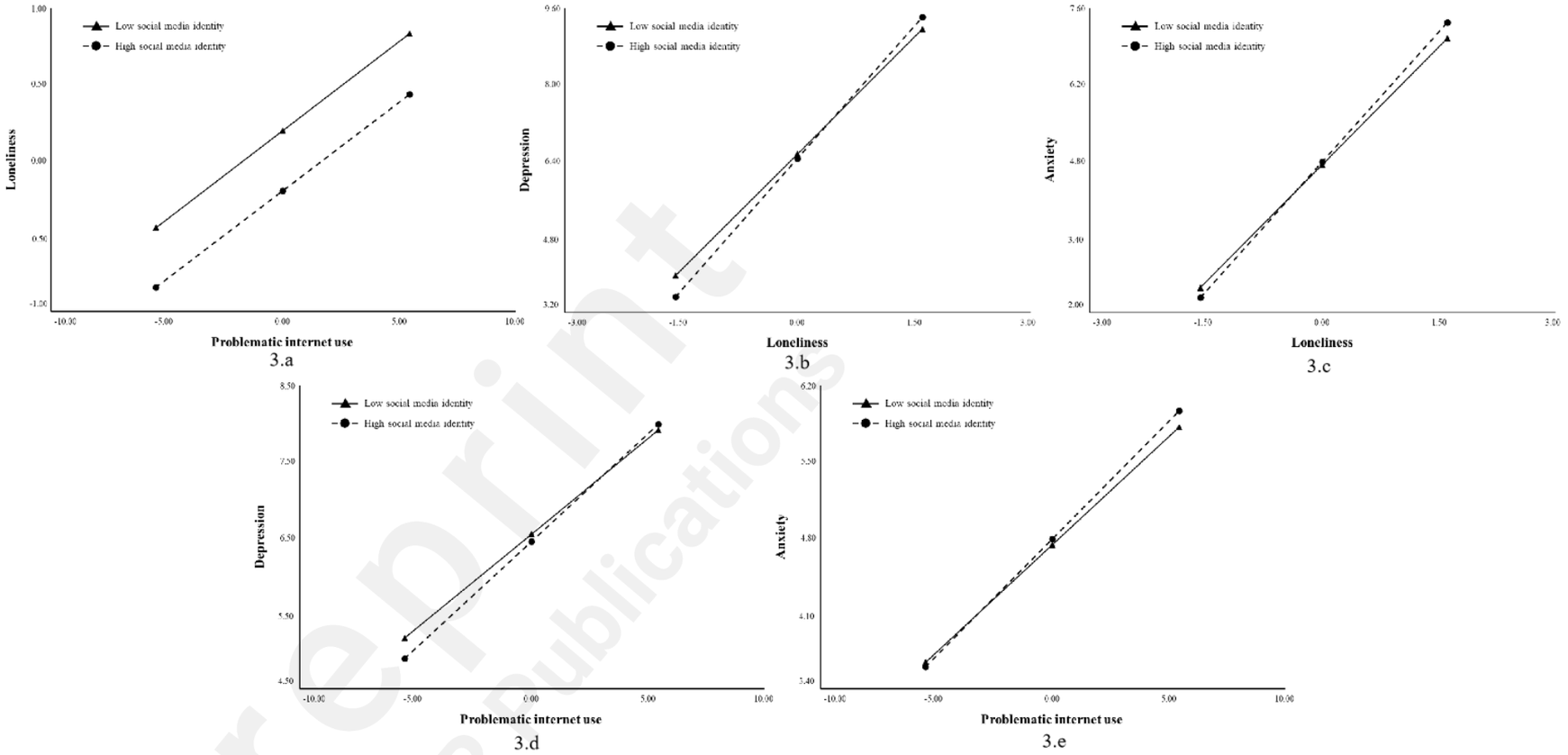

Figure 3. Moderation effects for the all paths of the direct and indirect effect of the mediational model

3.a: moderation effect of social media identity on the effect of PIU on loneliness; 3.b: moderation effect of social media identity on the effect of loneliness on depression; 3.c: moderation effect of social media identity on the effect of loneliness on anxiety; 3.d: moderation effect of social media identity on the effect of PIU on depression; 3.e: moderation effect of social media identity on the effect of PIU on anxiety.

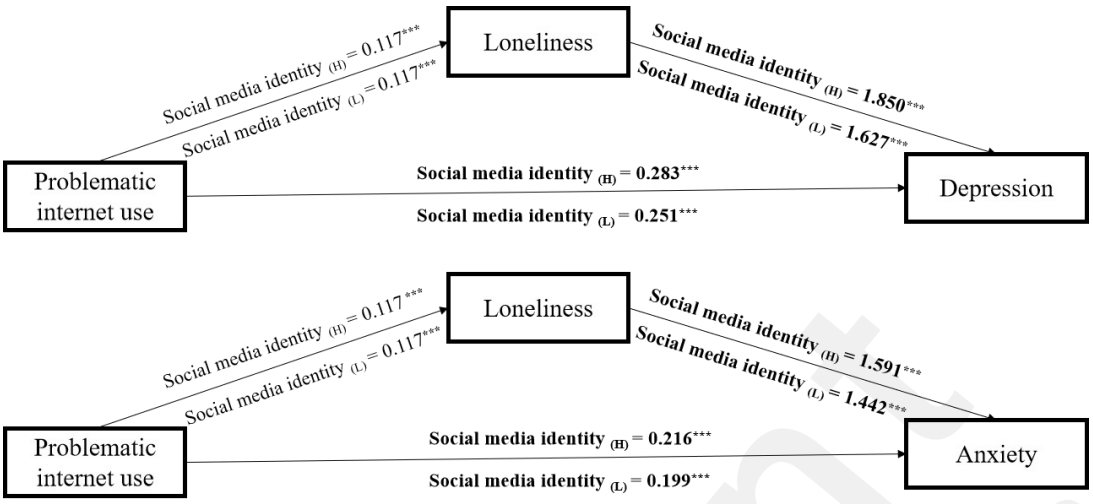

Figure 4. Moderated mediating model for individuals with lower (L) vs. higher (H) social media identity.

Bold paths and values indicated significantly different between different levels of social media identity.

*** p < 0.05, ** p < 0.01, *** p < 0.001.**

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Availability of data and materials

The datasets used and analyzed in this study will be made available by the corresponding author upon reasonable request.

Supplementary Tables S1-S6

Table S1 Demographics of participants

Characteristics	Number (N)	Percentage (%)
Gender		
Male	10596	49.77%
Female	10696	50.23%
Age group		
<18	2103	9.88%
>=18 & <30	6195	29.10%
>=30 & <40	2951	13.86%
>=40 & <50	3572	16.78%
>=50 & <60	2614	12.28%
>=60 & <70	2215	10.40%
>=70	1642	7.71%
Educational level		
No formal education	1064	5.00%
Primary school	2122	9.97%
Junior high school	3455	16.23%
Senior high school/Technical secondary school	5080	23.86%
University/Junior college	8759	41.14%
Postgraduate	812	3.81%
Employment		
Full-time students	6453	30.31%
Employed	7445	34.97%
Freelancer	2548	11.97%
Retirement	2658	12.48%
Unemployed	2188	10.28%
Average family income (per person)		
<=1000	1242	5.83%
>1000 & <=2000	2388	11.22%
>2000 & <=3000	3270	15.36%
>3000 & <=4000	3598	16.90%
>4000 & <=5000	2920	13.71%
>5000 & <=6000	2332	10.95%
>6000	5542	26.03%
Marital status		
Unmarried	8336	39.15%
Married	12053	56.61%
Divorce/widowed	903	4.24%
Living area		
Rural	6462	30.35%
Urban	14830	69.65%
Living Regions		

North	4398	20.66%
Northeast	1336	6.27%
East	4213	19.79%
Central	1989	9.34%
South	2635	12.38%
Southwest	2978	13.99%
Northwest	3743	17.58%
Chronic disease		
Yes	5432	25.51%
No	15860	74.49%

Table S2 Differences of variables between participants with various demographics

Characteristics	Loneliness	p value	PIU	p value	Social Media Identity	p value	Depression	p value	Anxiety	p value
Gender		<0.001		0.101		0.040		0.068		0.003
Male	1.519 (1.613)		5.913 (5.622)		31.235 (11.310)		6.523 (5.765)		4.728 (4.737)	
Female	1.623 (1.606)		5.678 (5.294)		31.005 (10.668)		6.456 (5.238)		4.780 (4.502)	
Age group		<0.001		<0.001		<0.001		<0.001		<0.001
<18	1.673 (1.796)		7.556 (5.805)		31.646 (11.474)		6.859 (6.427)		5.014 (5.319)	
>=18 & <30	1.859 (1.684)		7.896 (5.362)		32.318 (10.031)		7.230 (5.628)		5.302 (4.865)	
>=30 & <40	1.627 (1.590)		6.075 (5.352)		31.259 (10.897)		6.796 (5.551)		5.066 (4.693)	
>=40 & <50	1.384 (1.490)		4.901 (4.897)		30.521 (11.055)		6.139 (5.077)		4.392 (4.253)	
>=50 & <60	1.209 (1.444)		4.067 (4.757)		29.909 (11.983)		5.484 (5.125)		4.017 (4.208)	
>=60 & <70	1.360 (1.490)		3.530 (4.904)		31.373 (10.522)		5.727 (5.264)		4.262 (4.218)	
>=70	1.525 (1.560)		2.864 (4.506)		28.558 (12.101)		6.065 (5.000)		4.420 (4.156)	
Educational level		<0.001		<0.001		<0.001		<0.001		<0.001
No formal education	1.490 (1.551)		3.367 (4.973)		28.648 (12.115)		6.262 (5.320)		4.724 (4.358)	
Primary school	1.316 (1.479)		3.639 (4.752)		29.667 (11.917)		5.649 (5.016)		4.162 (4.108)	
Junior high school	1.266 (1.531)		4.741 (5.228)		30.060 (11.420)		5.679 (5.418)		4.159 (4.467)	
Senior high school/Technical secondary school	1.649 (1.673)		6.344 (5.598)		31.316 (10.745)		6.681 (5.628)		4.874 (4.738)	
University/Junior college	1.714 (1.611)		6.598 (5.380)		31.851 (10.510)		6.883 (5.479)		5.022 (4.674)	
Postgraduate	1.619 (1.675)		7.010 (5.600)		33.537 (10.355)		6.995 (6.226)		5.245 (5.140)	
Employment		<0.001		<0.001		<0.001		<0.001		<0.001
Full-time student	1.870 (1.725)		8.140 (5.448)		32.261 (10.469)		7.211 (5.849)		5.233 (5.021)	

Employed	1.446 (1.539)		5.507 (5.193)		31.324 (10.923)		6.241 (5.311)		4.600 (4.462)	
Freelancer	1.365 (1.530)		4.539 (5.010)		30.094 (11.347)		6.168 (5.376)		4.535 (4.465)	
Retirement	1.412 (1.499)		3.666 (4.817)		30.842 (11.409)		5.859 (5.126)		4.275 (4.189)	
Unemployed	1.551 (1.596)		3.910 (5.113)		28.586 (11.278)		6.349 (5.506)		4.707 (4.484)	
Average family income (per person)		<0.001		<0.001		<0.001		<0.001		<0.001
<=1000	1.995 (1.725)		5.714 (5.947)		27.192 (11.899)		8.033 (6.301)		5.861 (5.243)	
>1000 & <=2000	1.536 (1.604)		5.292 (5.391)		28.420 (11.677)		6.290 (5.343)		4.550 (4.509)	
>2000 & <=3000	1.546 (1.580)		5.423 (5.258)		29.786 (11.090)		6.458 (5.374)		4.705 (4.519)	
>3000 & <=4000	1.445 (1.567)		5.192 (5.247)		31.442 (10.428)		5.897 (5.252)		4.327 (4.312)	
>4000 & <=5000	1.548 (1.568)		5.827 (5.325)		31.496 (10.796)		6.348 (5.277)		4.669 (4.420)	
>5000 & <=6000	1.509 (1.580)		5.983 (5.222)		31.884 (10.333)		6.331 (5.387)		4.587 (4.538)	
>6000	1.622 (1.649)		6.546 (5.705)		33.219 (10.582)		6.774 (5.711)		5.017 (4.853)	
Marital status		<0.001		<0.001		<0.001		<0.001		<0.001
Unmarried	1.863 (1.717)		7.950 (5.497)		32.024 (10.566)		7.318 (5.885)		5.331 (5.030)	
Married	1.339 (1.485)		4.448 (4.948)		30.756 (11.010)		5.869 (5.138)		4.335 (4.263)	
Divorce/widowed	1.981 (1.672)		3.891 (5.176)		27.609 (12.363)		7.128 (5.575)		5.027 (4.682)	
Living area		0.013		0.009		<0.001		<0.001		<0.001
Rural	1.611 (1.616)		5.688 (5.516)		30.411 (10.777)		6.739 (5.564)		4.933 (4.609)	
Urban	1.554 (1.607)		5.842 (5.436)		31.428 (11.072)		6.381 (5.478)		4.677 (4.624)	
Living Regions		<0.001		<0.001		<0.001		<0.001		<0.001
North	1.465 (1.644)		5.937 (5.706)		32.352 (10.983)		6.320 (5.830)		4.582 (4.813)	
Northeast	1.844 (1.610)		6.966 (5.717)		31.321 (10.893)		7.622 (5.862)		5.686 (5.012)	
East	1.558 (1.577)		5.635 (5.260)		30.241 (11.629)		6.283 (5.214)		4.589 (4.426)	
Central	1.772 (1.656)		6.099 (5.588)		29.631 (11.666)		7.011 (5.378)		4.957 (4.642)	
South	1.513 (1.589)		5.280 (5.276)		31.719 (10.711)		6.122 (5.583)		4.572 (4.743)	

Southwest	1.757 (1.641)	5.871 (5.430)	31.186 (10.278)	6.805 (5.386)	4.942 (4.588)	
Northwest	1.402 (1.536)	5.533 (5.303)	30.903 (10.489)	6.248 (5.332)	4.683 (4.332)	
Chronic disease	<0.001	<0.001	<0.001	<0.001	<0.001	
Yes	1.767 (1.635)	5.064 (5.484)	29.926 (11.268)	7.282 (5.525)	5.392 (4.729)	
No	1.504 (1.596)	6.050 (5.431)	31.528 (10.867)	6.218 (5.474)	4.536 (4.563)	

Table S3 The moderated mediation model regarding depression

Predictors	Mediation model						Moderated mediation model					
	Model 1 (Y=Loneliness)		Model 2 (Y=Depression)		Model 3 (Y=Anxiety)		Model 4 (Y=Loneliness)		Model 5 (Y=Depression)		Model 6 (Y=Anxiety)	
	β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI
PIU	0.116	(0.112, 0.120)	0.272	(0.261, 0.284)	0.212	(0.202, 0.222)	0.117	(0113, 0.121)	0.267	(0.255, 0.279)	0.207	(0.198, 0.217)
Loneliness			1.743	(1.705, 1.781)	1.514	(1.482, 1.546)			1.739	(1.700, 1.778)	1.516	(1.484, 1.549)
Social media identity							(0.018)	(-0.020, -0.016)	(0.005)	(-0.001, 0.001)	0.002	(-0.002, 0.007)
Social media identity × PIU							0.000	(-0.003, 0.003)	0.002	(0.001, 0.002)	0.001	(0.000, 0.002)
Social media identity ×loneliness									0.010	(0.007, 0.013)	0.007	(0.004, 0.010)
F	160.675		519.443		502.896		165.462		481.285		464.138	
R^2	0.200		0.454		0.446		0.214		0.456		0.447	

Table S4 The moderated mediation model regarding depression

Predictors	Model 1 (Y=Loneliness)		Model 2 (Y=Depression)		Model 3 (Y=Anxiety)		Model 4 (Y=Loneliness)		Model 5 (Y=Depression)		Model 6 (Y=Anxiety)	
	β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI
Male												
PIU	0.116	(0.111, 0.121)	0.271	(0.255, 0.288)	0.209	(0.196, 0.223)	0.116	(0.111, 0.121)	0.261	(0.245, 0.278)	0.202	(0.189, 0.216)
Loneliness			1.862	(1.806, 1.917)	1.590	(1.544, 1.635)			1.858	(1.802, 1.913)	1.592	(1.546, 1.638)
Social media identity							(0.016)	(-0.019, -0.014)	0.003	(-0.004, 0.011)	0.008	(0.001, 0.014)
Social media identity × PIU							0.000	(-0.000, 0.001)	0.002	(0.001, 0.004)	0.001	(0.000, 0.002)
Social media identity × Loneliness									0.013	(0.009, 0.018)	0.010	(0.006, 0.013)
F	91.094		294.754		291.612		92.263		274.240		270.016	
R^2	0.216		0.479		0.477		0.229		0.483		0.479	
Female												
PIU	0.117	(0.111, 0.122)	0.270	(0.253, 0.286)	0.211	(0.197, 0.226)	0.118	(0.112, 0.123)	0.270	(0.253, 0.287)	0.211	(0.196, 0.225)
Loneliness			1.625	(1.573, 1.677)	1.438	(1.392, 1.483)			1.612	(1.560, 1.665)	1.435	(1.389, 1.481)
Social media identity							(0.020)	(-0.023, -0.018)	(0.015)	(-0.022, -0.007)	(0.004)	(-0.010, 0.003)
Social media identity × PIU							(0.001)	(-0.001, 0.000)	0.000	(-0.001, 0.002)	0.000	(-0.001, 0.001)
Social media identity × Loneliness									0.006	(0.001, 0.010)	0.003	(-0.001 0.007)

F		76.814		243.047		230.224		80.493		223.891		211.202
R^2		0.187		0.429		0.416		0.204		0.431		0.416
Age: 12-17 (Not adjust for education & employment & married status)												
PIU	0.120	(0.108, 0.131)	0.212	(0.175, 0.250)	0.170	(0.140, 0.201)	0.122	(0.111, 0.134)	0.213	(0.176, 0.251)	0.168	(0.137, 0.199)
Loneliness			2.007	(1.881, 2.133)	1.741	(1.637, 1.845)			1.994	(1.867, 2.121)	1.739	(1.635, 1.844)
Social media identity							(0.019)	(-0.025, -0.014)	(0.009)	(-0.026, 0.001)	0.000	(-0.014, 0.015)
Social media identity × PIU							(0.000)	(-0.001, 0.001)	(0.001)	(-0.004, 0.002)	0.001	(-0.002, 0.003)
Social media identity × Loneliness									0.015	(0.006, 0.025)	0.006	(-0.002, 0.014)
F		38.312		101.587		103.280		37.477		90.188		91.070
R^2		0.279		0.518		0.522		0.293		0.521		0.523
Age: 18-29 (Not adjust for employment & married status)												
PIU	0.117	(0.110, 0.124)	0.268	(0.247, 0.290)	0.206	(0.187, 0.225)	0.117	(0.109, 0.124)	0.262	(0.241, 0.284)	0.204	(0.185, 0.223)
Loneliness			1.634	(1.565, 1.704)	1.450	(1.390, 1.511)			1.628	(1.559, 1.698)	1.446	(1.385, 1.507)
Social media identity							(0.024)	(-0.027, -0.020)	(0.004)	(-0.015, 0.007)	(0.004)	(-0.013, 0.006)
Social media identity × PIU							(0.000)	(-0.001, 0.001)	0.004	(0.002, 0.006)	0.002	(0.000, 0.003)
Social media identity × Loneliness									0.000	(-0.006, 0.006)	(0.000)	(-0.006, 0.005)

F		61.482		213.255		200.838		63.718		189.036		177.039
R^2		0.173		0.432		0.417		0.192		0.434		0.418
Age: 30-39												
PIU	0.112	(0.102, 0.122)	0.223	(0.193, 0.253)	0.168	(0.142, 0.194)	0.110	(0.100, 0.120)	0.218	(0.188, 0.248)	0.164	(0.138, 0.190)
Loneliness			1.929	(1.829, 2.029)	1.653	(1.565, 1.740)			1.915	(1.814, 2.016)	1.646	(1.558, 1.734)
Social media identity							(0.017)	(-0.022, -0.013)	(0.008)	(-0.022, 0.006)	(0.001)	(-0.013, 0.011)
Social media identity × PIU							0.001	(-0.000, 0.002)	0.002	(-0.000, 0.005)	0.002	(0.000, 0.005)
Social media identity × Loneliness									0.005	(-0.004, 0.013)	(0.001)	(-0.008, 0.007)
F		27.281		105.058		92.094		27.873		95.421		83.412
R^2		0.201		0.502		0.469		0.217		0.503		0.470
Age: 40-49												
PIU	0.120	(0.111, 0.129)	0.239	(0.210, 0.268)	0.193	(0.169, 0.218)	0.120	(0.110, 0.129)	0.228	(0.199, 0.257)	0.183	(0.159, 0.208)
Loneliness			1.700	(1.606, 1.795)	1.445	(1.365, 1.525)			1.698	(1.603, 1.793)	1.465	(1.384, 1.515)
Social media identity							(0.019)	(-0.023, -0.015)	(0.004)	(-0.016, 0.008)	0.013	(0.003, 0.023)
Social media identity × PIU							0.000	(-0.000, 0.001)	0.004	(0.002, 0.007)	0.003	(0.001, 0.005)
Social media identity × Loneliness									0.018	(0.010, 0.026)	0.014	(0.007, 0.020)
F		33.317		96.795		93.060		34.907		90.116		86.114
R^2		0.202		0.433		0.424		0.222		0.441		0.430

Age: 50-59												
PIU	0.113	(0.103, 0.124)	0.287	(0.252, 0.321)	0.210	(0.182, 0.239)	0.113	(0.102, 0.124)	0.286	(0.251, 0.321)	0.206	(0.177, 0.234)
Loneliness			1.730	(1.616, 1.845)	1.522	(1.428, 1.616)			1.738	(1.623, 1.853)	1.532	(1.438, 1.626)
Social media identity							(0.009)	(-0.014, -0.005)	0.002	(-0.012, 0.015)	0.009	(-0.002, 0.020)
Social media identity × PIU							0.000	(-0.001, 0.001)	(0.003)	(-0.006, 0.000)	(0.001)	(-0.003, 0.002)
Social media identity × Loneliness									0.014	(0.004, 0.023)	0.014	(0.006, 0.022)
F		23.262		71.718		72.318		22.434		65.220		66.122
R^2		0.195		0.437		0.439		0.201		0.439		0.443
Age: 60-69												
PIU	0.110	(0.098, 0.122)	0.357	(0.321, 0.393)	0.267	(0.238, 0.295)	0.112	(0.100, 0.124)	0.337	(0.300, 0.374)	0.255	(0.226, 0.284)
Loneliness			1.730	(1.612, 1.849)	1.504	(1.412, 1.597)			1.739	(1.620, 1.857)	1.516	(1.423, 1.610)
Social media identity							(0.018)	(-0.024, -0.012)	(0.002)	(-0.018, 0.015)	0.002	(-0.011, 0.014)
Social media identity × PIU							0.000	(-0.001, 0.001)	0.005	(0.001, 0.009)	0.002	(-0.001, 0.005)
Social media identity × Loneliness									0.025	(0.014, 0.036)	0.019	(0.011, 0.028)
F		18.876		73.021		80.171		19.266		68.690		74.204
R^2		0.189		0.483		0.507		0.204		0.494		0.513
Age: >=70												
PIU	0.102	(0.085, 0.119)	0.336	(0.289, 0.383)	0.28	(0.243,	0.098	(0.080, 0.116)	0.347	(0.297, 0.396)	0.286	(0.244, 0.327)

				2	0.321)					
Loneliness		1.381	(1.251, 1.511)	1.17 6	(1.068, 1.285)			1.364	(1.233, 1.495)	1.166	(1.057, 1.275)
Social media identity						(0.012)	(-0.018, -0.005)	(0.028)	(-0.045, -0.011)	(0.014)	(-0.028, 0.001)
Social media identity × PIU						0.002	(0.001, 0.004)	(0.001)	(-0.005, 0.002)	(0.000)	(-0.003, 0.003)
Social media identity × Loneliness								0.007	(-0.004, 0.017)	0.003	(-0.006, 0.011)
F	9.937		40.068		39.034		10.287		36.780		35.410
R^2	0.143		0.410		0.404		0.156		0.415		0.405

Table S5 The mediation model of loneliness on depression and anxiety via PIU

Predictors	Model 1 (Y=PIU)		Model 2 (Y=Depression)		Model 3 (Y=Anxiety)		Model 4 (Y=Depression)		Model 5 (Y=Anxiety)	
	β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI
Loneliness	1.230	(1.189, 1.270)	2.078	(2.041, 2.115)	1.774	(1.743, 1.805)	1.743	(1.705, 1.781)	1.514	(1.482, 1.546)
PIU							0.272	(0.261, 0.284)	0.212	(0.202, 0.222)
F	229.545		429.487		428.869		519.443		502.896	
R^2	0.263		0.400		0.400		0.454		0.446	

Table S6 Total, direct and indirect effect based on mediation model of loneliness on depression and anxiety via PIU

Total, direct and indirect effect	Depression				Anxiety			
	Effect size	SE	LLCI	ULCI	Effect size	SE	LLCI	ULCI
Total effect	2.078	0.188	2.041	2.115	1.774	0.016	1.743	1.805
Direct effect	1.743	0.194	1.705	1.781	1.514	0.016	1.482	1.546
Indirect effect	0.335	0.012	0.311	0.358	0.260	0.010	0.242	0.280

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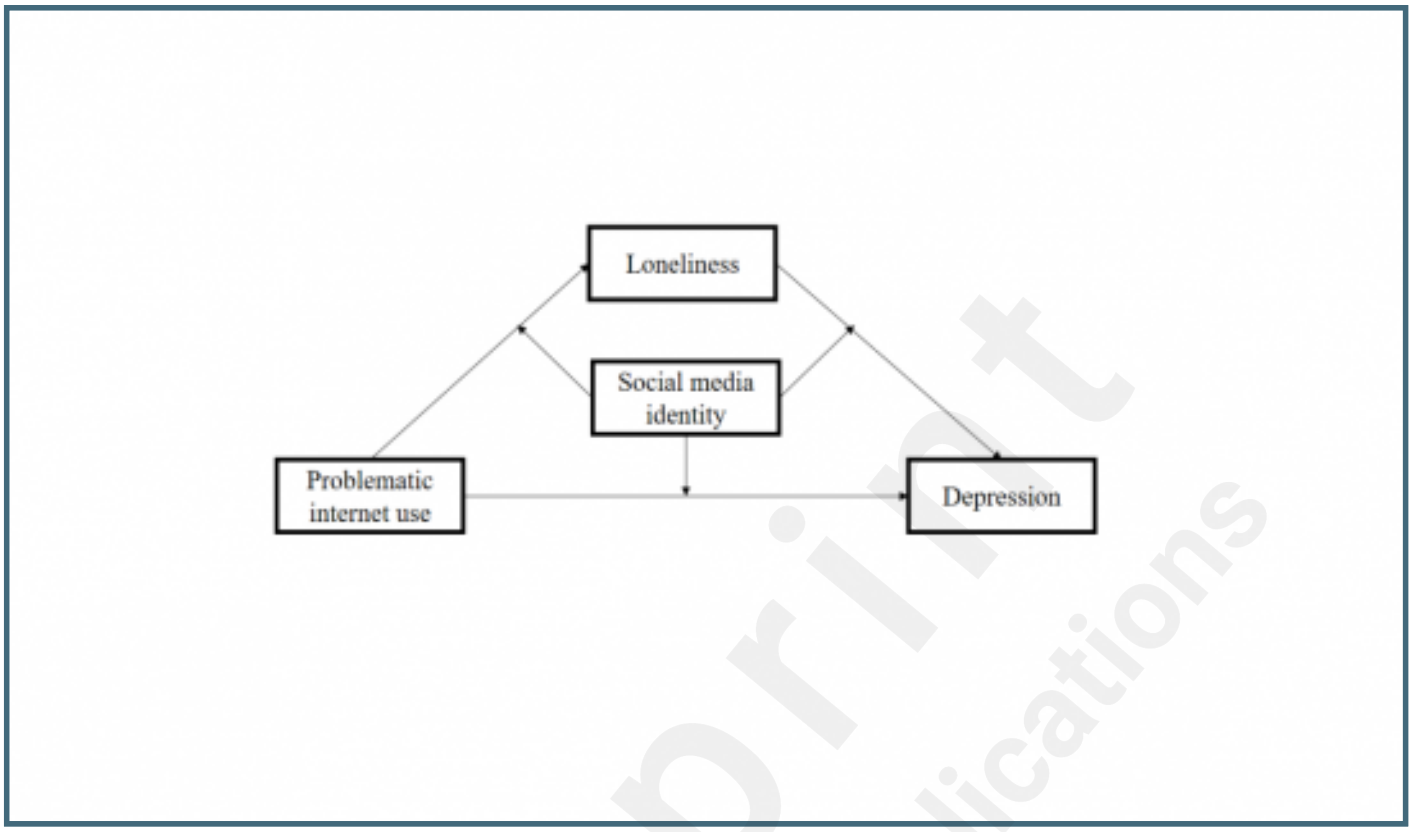
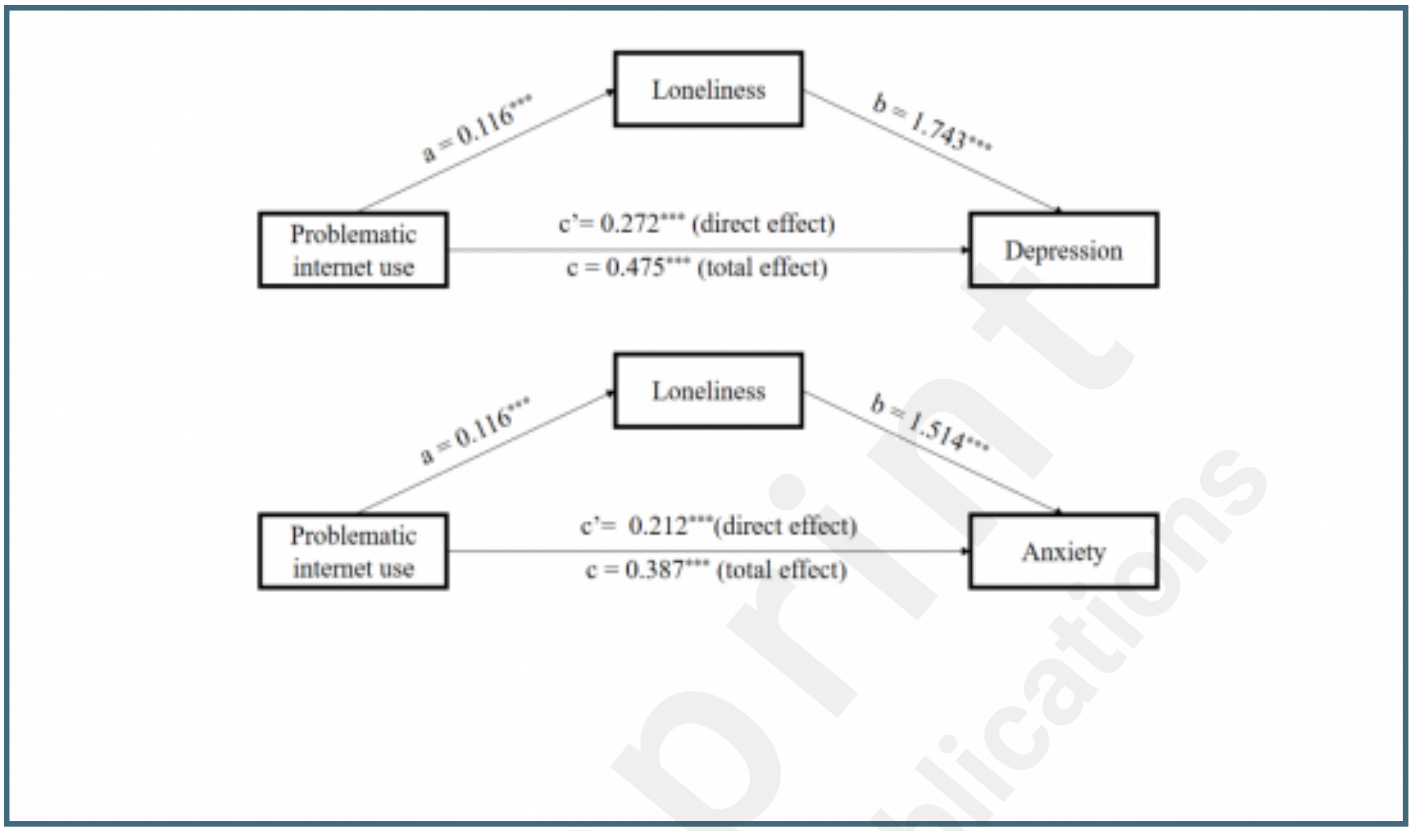
Supplementary Files

Figures

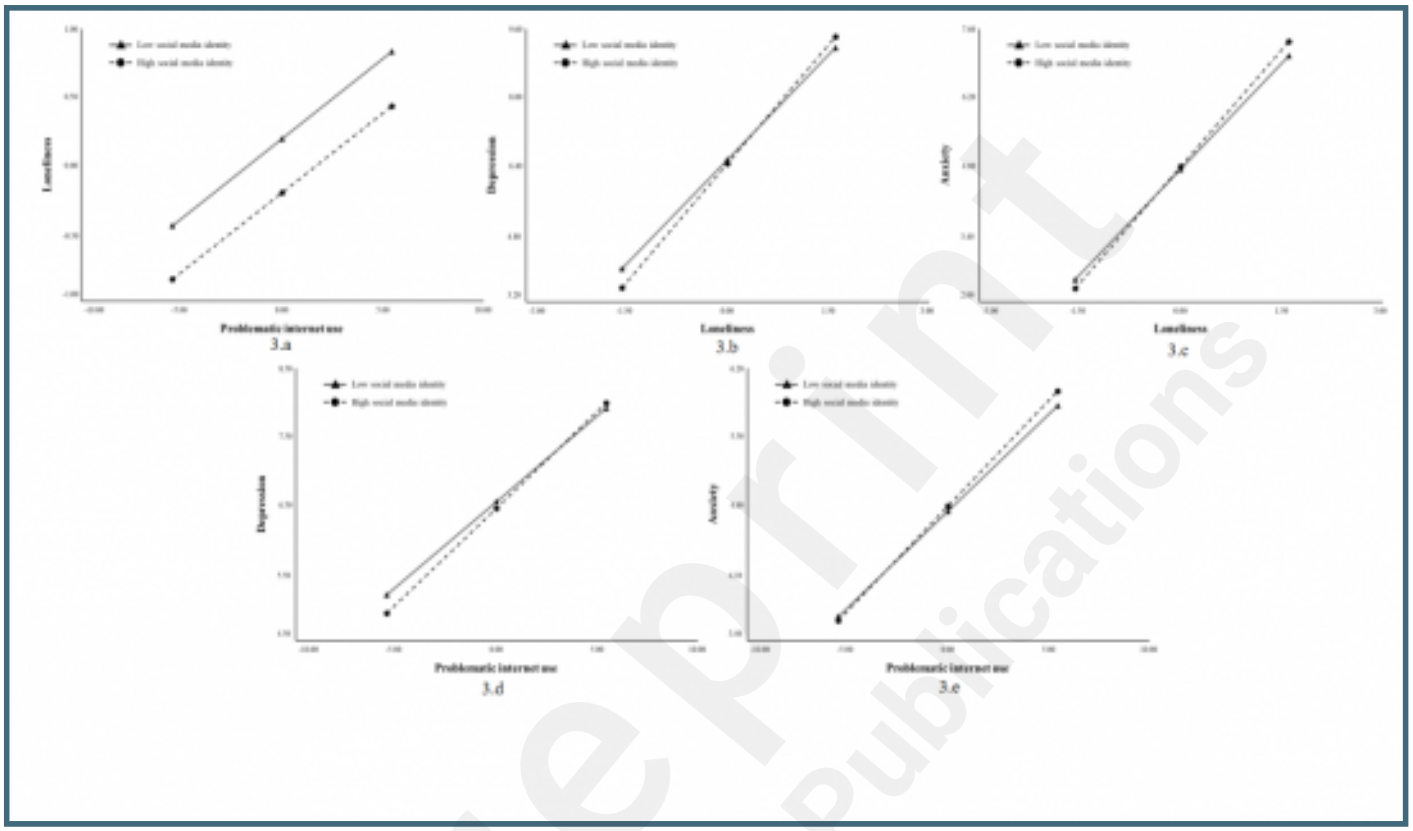
The hypothesized moderated mediation model.



Mediating model of problematic internet use on depression and anxiety via loneliness. * p < 0.05, ** p < 0.01, *** p < 0.001.



Moderation effects for the all paths of the direct and indirect effect of the mediational model. 3.a: moderation effect of social media identity on the effect of PIU on loneliness; 3.b: moderation effect of social media identity on the effect of loneliness on depression; 3.c: moderation effect of social media identity on the effect of loneliness on anxiety; 3.d: moderation effect of social media identity on the effect of PIU on depression; 3.e: moderation effect of social media identity on the effect of PIU on anxiety.



Moderated mediating model for individuals with lower (L) vs. higher (H) social media identity. Bold paths and values indicated significantly different between different levels of social media identity. * p < 0.05, ** p < 0.01, *** p < 0.001.