Association between internet addiction and insomnia among college freshmen: the chain mediation effect of emotion regulation and anxiety and the moderating role of gender

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Abstract

Background The advancement of the information age has led to the widespread use of the internet, accompanied by numerous internet-related issues that often correlate with various physical and mental health conditions, particularly among college freshmen. We examined the relationship between internet addiction (IA) and insomnia among these students, using emotion regulation (ER) and anxiety as mediators and gender as a moderating variable.

Methods This cross-sectional study included 7,353 freshmen from a university in Jingzhou City, Hubei Province, China. Data were collected through an online self-administered questionnaire, including the Internet Addiction Test (IAT), the Emotion Regulation subscale (ER), the Generalized Anxiety Disorder 7-item scale (GAD-7), and the Insomnia Severity Index (ISI). Data analysis was conducted using SPSS 21.0 and PROCESS version 4.1 to test the hypothesized relationships among variables.

Results In our survey, correlation analysis showed that ER was significantly negatively correlated with IA, anxiety, and insomnia; IA was significantly positively correlated with anxiety and insomnia (all $p < 0.01$). The mediating effect analysis indicated that IA was a significant positive predictor of insomnia. ER and anxiety played a chain - mediating role in the development of insomnia ($\beta = 0.039$, 95% confidence interval = 0.035–0.043). The moderating effect analysis showed that the interaction term of IA and gender had a significant negative predictive effect on ER ($\beta = -0.014$, 95% confidence interval [-0.027, -0.001]) and insomnia ($\beta = -0.022$, 95% confidence interval [-0.036, -0.007]). Males (direct effect: $\beta = 0.048$, 95% confidence interval = [0.037, 0.059]) had a stronger predictive ability for the level of insomnia than females (direct effect: $\beta = 0.026$, 95% confidence interval = [0.014, 0.037]). Females (indirect effect 1: $\beta = 0.015$, 95% confidence interval = [0.010, 0.020]; indirect effect 2: $\beta = 0.041$, 95% confidence interval = [0.037, 0.045])

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had a stronger predictive ability for the level of insomnia through the level of IA than males (indirect effect 1: β = 0.014, 95% confidence interval = [0.009, 0.018]; indirect effect 2: β = 0.037, 95% confidence interval = [0.033, 0.041]).

Conclusion IA can exacerbate insomnia in college freshmen by compromising their ER, subsequently triggering anxiety symptoms. The process differs by gender, suggesting tailored strategies for each. These findings may play crucial roles in promoting the physical and mental well-being of college freshmen.

Keywords Internet addiction, Insomnia, Emotion regulation, Anxiety, College freshmen

Introduction

Over the past 20 years, there has been a steady increase in research interest in insomnia among college students. It has been reported that 26.4% of college students suffer from this sleep disorder [1]. Almost 60% of college students have poor sleep quality, and 7.7% meet the criteria for insomnia [2]. In addition, the use of the internet is increasing annually, especially among young people [3]. According to statistics, the global number of internet users will reach 5.35 billion in 2024, accounting for 66.2% of the world's total population, an increase of 1.8% compared with that in 2023 [4].

For college freshmen, this impact may be even more pronounced [5]. Some research shows that younger college students (aged 18–20) are more prone to social media addiction than older students (aged 21–24 and 25–29), and the main medium for social media addiction is the Internet [6, 7]. Data from 2,355 college students in Wuhan from 2021 to 2022 indicates that age and grade are protective factors against IA [8]. As the grade level increases, the risk of IA decreases. Therefore, IA among freshmen in college requires more attention than that among students in higher grades. IA among college students is often accompanied by a series of mental health issues, including insomnia, anxiety, and decreased ER abilities, which increase their risk of academic failure and harm their quality of life [9].

In summary, the prevalence of insomnia among college students is high and significantly correlated with mental health status. Additionally, college students are at high risk for IA, and the connection between these two issues seems to be increasingly tight. Therefore, it is extremely important to explore the development process of insomnia and IA among college students. Given that college freshmen are a special and crucial stage of university life, this paper aims to investigate the relationship between IA and insomnia among college freshmen.

IA and insomnia

Insomnia refers to self - reported poor sleep quality or insufficient sleep despite having adequate sleep opportunities and a sleep - conducive environment, accompanied by impaired daytime function [10]. Currently, the theoretical models of insomnia can be summarized in four aspects. First, personal characteristics such as anxiety or perfectionism. Second, stressful events. Third, behaviors that maintain insomnia, such as staying in bed while awake or excessive napping. Fourth, Pavlovian conditioning, that is, the arousal triggered by the response to the bedroom environment [11]. IA refers to the abnormal, problematic, or excessive use of the Internet, which interferes with daily life [12]. Similar to other forms of addiction such as substance abuse, IA is mainly manifested as a strong impulse to use the Internet, the need to spend more and more time online to achieve the same level of satisfaction, and adverse effects on mental health, social life, and academic or professional performance [13]. The severity of IA is correlated with the severity of insomnia [14]. High incidences of IA and insomnia are observed among Chinese university students [15]. In addition, a research report on 141 subjects pointed out that among ordinary Internet users, only 7.1% of them suffered from insomnia. Among those with mild IA, 30.4% reported having insomnia. Surprisingly, the proportion of those with moderate IA who experienced insomnia was as high as 86.8%, and all subjects with IA reported having insomnia [7]. Therefore, we hypothesize that IA positively predicts insomnia.

IA, ER, anxiety and insomnia

ER refers to the ability to effectively manage and control one's emotions [16], encompassing the intensity, duration, and mode of expression of emotions. It involves the strategies people use to manage and change their emotional states, including cognitive reappraisal, suppression, and problem - solving [17]. Anxiety refers to a state of fear or worry in response to a perceived threat, whether current or future, leading to physiological reactions such as muscle tension and cautious behavior [18, 19]. As a normal emotional response, anxiety can "alert" people to potential dangers. However, when anxiety is inappropriate, severe, persistent, and impairs functioning, it turns into a disorder [20]. Effective ER plays a vital role in controlling anxiety levels. Enhancing ER skills has the potential to assist individuals in better coping with anxiety symptoms, particularly during periods of heightened stress [21]. IA severely affects individual ER. Among adolescents, IA is usually comorbid with emotional symptoms [22]. The negative impact on emotions may prompt addicts to go online again to alleviate their emotional

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problems, thus creating a vicious circle of dependence and emotional instability [23]. IA is also inextricably linked to anxiety. As the level of IA increases, students' anxiety levels also increase [24]. Genetic studies have shown that insomnia risk genes significantly overlap with genes related to anxiety disorders, ER, and stress [25]. A study involving 55 participants pointed out that signs of poor sleep (shortened sleep duration or increased severity of insomnia) are associated with increased activity in brain regions related to emotion regulation [26]. The study found that adolescents with anxiety symptoms are 2.06 times more likely to experience insomnia symptoms than those without anxiety symptoms [27]. Anxiety plays a significant mediating role in the relationship between physical activity and sleep disorders [28]. Furthermore, anxiety symptoms can interact with difficulties in ER, influencing the severity of insomnia [29]. Specifically, decreased ER ability can amplify the negative impact of anxiety on sleep, suggesting that ER may be a crucial factor in anxiety-induced insomnia. Therefore, we hypothesize that ER and anxiety mediate the relationship between IA and insomnia among college freshmen.

Moderating effect of gender

Gender serves as an independent influencing factor for many symptoms. An upwards trend in the prevalence of insomnia among females can be observed starting from adolescence, possibly linked to hormonal fluctuations [30]. Compared with males across different age groups, females generally report a greater incidence of insomnia symptoms. For example, during adolescence, the insomnia rate among females increases by 3.6 times, whereas among males, it increases by 2.1 times [31]. While there are no significant sex differences in the overall incidence of IA, there are distinct specific impacts and related behavioral manifestations between the sexes. For example, males are more likely to develop addictive behaviors toward online games, whereas females tend to have a greater addiction tendency toward social media platforms [32]. In males, addictive brain network connections are associated with craving, whereas in females, these connections are linked to negative emotions and maladaptive cognitive–emotional regulation strategies [33]. Notably, gender does not seem to be involved in the process of IA and anxiety. A study involving undergraduate students in Nigeria found that although physical exercise can moderate the relationship between IA and anxiety, gender does not have a significant moderating effect. This indicates that the impact of IA on anxiety is consistent across genders [34]. In a network analysis of nursing students, gender did not significantly affect the overall network structure of IA and anxiety symptoms, which further supports this view [35]. Therefore, we hypothesize that gender can moderate the direct impact of IA on insomnia. Additionally, gender may also mediate the indirect influence of IA on insomnia through ER and anxiety.

Hypothetical research model

Research on the pathways influencing insomnia among freshmen is scarce. Consequently, this study takes gender as a moderating variable and ER and anxiety symptoms as mediating variables to explore the moderated chain mediation between IA and insomnia. Specifically, three hypotheses are proposed in this study (Fig. 1):

H1 IA positively predicts insomnia.

H2 The relationship between IA and insomnia is mediated by ER and anxiety symptoms. Specifically, IA negatively affects ER, which in turn increases anxiety levels, and elevated anxiety positively influences the severity of insomnia.

H3 Gender moderates the relationship between IA and insomnia, and simultaneously, gender moderates the mediating mechanism between IA and insomnia.
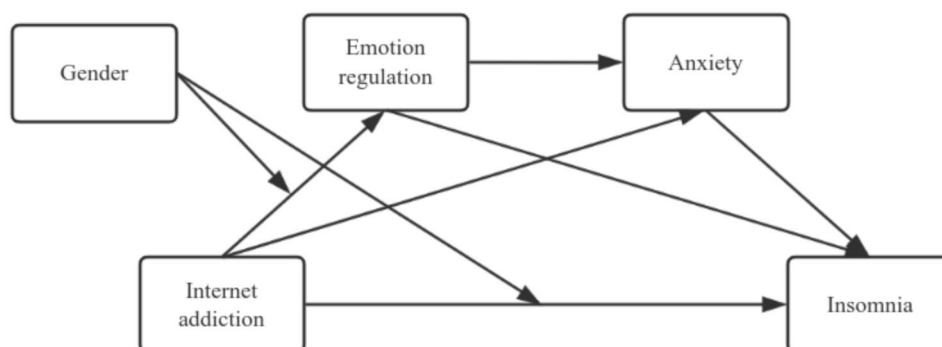

Fig. 1 Hypothesized model

Methods

Participants

This study conducted a cross-sectional survey among all college freshmen who were enrolled at Yangtze University in Jingzhou city, Hubei Province, in September 2023 via an online self-administered questionnaire from September to October 2023. We have signed a data confidentiality agreement to properly handle the data of participants and protect their privacy. At the beginning of the questionnaire, students are informed that the research covers aspects such as internet addiction, insomnia, emotion regulation, and anxiety. They are also told that the survey is time - consuming and offers no direct benefits, yet it is of significance to academic research. After students have a full understanding, they can voluntarily choose whether to participate. Meanwhile, participants are clearly informed that they have the right to withdraw at any time without suffering any adverse effects. The director of the Psychological Counseling Center of Yangtze University or full - time psychology teachers are responsible for sending the survey agreement to the counselors of the selected colleges and providing unified training. The counselors then sent the questionnaire links to the students via WeChat groups. Each student was required to carefully read the instructions on the purpose and method of completing the questionnaire. After excluding the data from participants who refused to complete certain indicators in the questionnaire or who completed it too quickly, we collected a total of 7,353 valid questionnaires, with an overall effective rate of 86.53%. All students were aware of the purpose of the study, and participated in it voluntarily. Informed consent was obtained from all the participants.The study was approved by the Ethics Committee of Jingzhou Mental Health Centre (no. 2024LL0801).

Measures

Internet addiction test (IAT)

The IAT questionnaire was developed by Kimberly S. Young and adapted from the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM - IV). It is used to assess an individual's tendency or severity of IA [36]. The questionnaire consists of 20 items. Each item is rated on a 5 - point Likert scale ranging from 1 (never) to 5 (always), with some items being reverse - scored. The scoring range is from 20 to 100 points. The higher the total score, the more severe the state of IA [37]. The Chinese version of the IAT questionnaire has good reliability and validity [38]. In this study, the Cronbach's alpha coefficient of IA was 0.863.

Emotional regulation (ER)

The ER Questionnaire uses the ER sub - scale from the Mental Health Scale for College Students (MHS - CS).

This questionnaire was developed by Huang Xiting and is used to assess the general emotional state and emotional control of college students [39, 40]. The questionnaire contains 4 items. Each item is rated on a 5 - point Likert scale from 1 (completely agree) to 5 (completely disagree), with some items being reverse - scored. The scoring range is from 4 to 20 points. The higher the score, the better the ER ability [40]. In this study, the Cronbach's alpha coefficient of ER was 0.798.

Generalized anxiety Disorder-7 (GAD-7)

The GAD – 7 scale was developed based on the diagnostic criteria for Generalized Anxiety Disorder (GAD) in the Diagnostic and Statistical Manual of Mental Disorders (DSM) and is used to assess anxiety symptoms in the past two weeks [41, 42]. The questionnaire contains 7 items. Each item is rated on a 4 - point scale from 0 (not at all) to 3 (nearly every day). The scoring range is from 0 to 21 points. The higher the total score, the more severe the degree of anxiety [42]. The Chinese version of the GAD-7 has good reliability and validity [43]. In this study, the Cronbach's alpha coefficient of this scale was 0.884.

Insomnia severity scale (ISI)

The ISI scale was developed by Dr. Charles M. Morin and is used to assess insomnia [44]. The questionnaire contains 7 items. Each item is rated on a 5 - point scale from 0 (no problem) to 4 (very severe). The scoring range is from 0 to 28 points. The higher the total score, the more severe the degree of insomnia [45]. The Chinese version of the ISI has good reliability and validity [46]. In this study, the Cronbach's alpha coefficient of this scale was 0.898.

Statistical analyses

The data were analysed via SPSS 21.0 (SPSS; IBM, Armonk, NY, USA) and PROCESS version 4.1 [47]. Medians (quartiles) for continuous variables and frequencies (proportional parts) for categorical variables were used to describe the basic characteristics of the participants. Mann−Whitney U tests and chi−square tests were used to compare differences in continuous and hierarchical variables between the insomnia and noninsomnia groups. Spearman correlation analyses explored the correlations of insomnia with IA, ER, and anxiety.

In PROCESS, the mediating effects of emotion regulation and anxiety were examined using Model 6, and the moderating effect of gender was examined using Model 86. Additionally, we examined the impact of internet addiction on insomnia through emotion regulation and anxiety among different genders (mean ± 1 standard deviation) (M − 1 SD, M + 1 SD). The significance of the indirect effects was tested using the Bootstrap method (with 5000 resamples) [48].

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Table 1 Demographic characteristics of study participants (*n* = 7353)

Variable	M ± SD (range) *n* (%)
IA	35.69 ± 10.73(20–92)
ER	14.62 ± 3.55(4–20)
Anxiety	4.26 ± 3.69(0–21)
Insomnia	4.65 ± 4.11(0–28)
Age (Years)	19.32–2.96(15–45)
Gender	
Male	3788(51.5)
Female	3565(48.5)
Place of birth	
Urban	1860(25.3)
County	1517(20.6)
Rural	3976(54.1)
One-child family status	
No	4936(67.1)
Yes	2417(32.9)
Economic status	
Excellent or good	165(2.2)
General	5338(72.6)
Very poor or poor	1850(25.2)
Parental work status	
All have	6063(82.5)
Father only	1007(13.7)
Mother only	170(2.3)
None	113(1.5)
Midnight snack	
No	6719(91.4)
Yes	634(8.6)
Physical activity	
More	877(11.9)
Normal	5011(68.1)
Less	1465(19.9)
Bedtime habits	
Before 22:00	312(4.2)
Between 22:00 and 24:00	5885(80.0)
After 24:00	1156(15.7)

Note. M, mean; SD, standard deviation

Table 2 Pearson's correlation coefficients between all study variables (*n* = 7353)

Variables	IA	ER	Anxiety	Insomnia
IA	1.000			
ER	-0.516**	1.000		
Anxiety	0.412**	-0.555**	1.000	
Insomnia	0.337**	-0.383**	0.540**	1.000

Note. ** *p* < 0.01

Results

Common-method deviation test

Since the data in this study were derived from self-reports, common method bias may exist. The Harman one-way test was used to test for common method bias. The results revealed that seven factors with more than 1 eigenroot were obtained without rotation, and the amount of variance explained by the first factor was 27.34% (< 40%). This shows that there is no significant common method bias in this study.

Descriptive statistics

Table 1 shows the basic information of the participants. The correlations of the main variables are shown in Table 2. ER was significantly negatively correlated with IA, anxiety and insomnia and significantly positively correlated with IA, anxiety and insomnia (all *p* < 0.01).

Mediating effect analysis

Table 3 elucidates the effect of IA on insomnia, controlling for seven covariates that may be relevant to this study (including place of birth, family economic status, one-child family status, parental work status, physical activity, bedtime habits, and midnight snack habits), as well as the mediating roles of ER and anxiety. The results revealed that IA was a statistically significant positive predictor of insomnia ($\beta = 0.119$, $p < 0.001$). Thus, H1 is supported. Table 4 shows a significant total effect between IA and insomnia ($\beta = 0.119$, 95% CI = 0.110–0.127). ER ($\beta = 0.013$, 95% CI = 0.008–0.018) and anxiety ($\beta = 0.029$, 95% CI = 0.024–0.033) had significant effects on insomnia. The ER and anxiety chain mediated the development of insomnia ($\beta = 0.039$, 95% CI = 0.035–0.043). Therefore, H2 is supported.

Moderating effect analysis

The gender variable was incorporated into Model 86 to test its moderating effect (Fig. 2). The results are shown in Table 5. The interaction term of internet addiction and gender had a significant negative predictive effect on emotion regulation ($\beta = -0.014$, 95% confidence interval [-0.027, -0.001]) and insomnia ($\beta = -0.022$, 95% confidence interval [-0.036, -0.007]).

To further analyse the moderating effect, we plotted its slope curve. The moderating variables for gender ± 1 standard deviation were the female group (M + 1 SD) and the male group (M-1 SD). The results in Figs. 3 and 4; Table 6 show that gender moderates the relationship between IA and insomnia. Men (direct effect: $\beta = 0.048$, 95% CI = [0.037, 0.059]) predicted the level of insomnia more strongly than women did (direct effect: $\beta = 0.026$, 95% CI = [0.014, 0.037]). Women (indirect effect 1: $\beta = 0.015$, 95% CI = [0.010, 0.020]; indirect effect 2: $\beta = 0.041$, 95% CI = [0.037, 0.045]) were better predictors of insomnia levels by level of IA than men (indirect effect 1: $\beta = 0.014$, 95% CI = [0.009, 0.018]; indirect effect 2: $\beta = 0.037$, 95% CI = [0.033, 0.041]) were more likely to predict insomnia through ER or to influence anxiety and thus predict insomnia levels through ER. Therefore, H3 was supported.

**Table 3** Regression results of the chain mediating effects model (*n* = 7353)

Outcome variable	Predictive variable	R^2	F	β	t	LLCI	ULCI
Equation 1							
ER	IA	0.279	355.188***	-0.160***	-47.076	-0.167	-0.154
Equation 2							
Anxiety	IA	0.332	404.673***	0.057***	14.769	0.05	0.065
	ER			-0.485***	-41.501	-0.508	-0.462
Equation 3							
Insomnia	IA	0.317	341.174***	0.038***	8.594	0.03	0.047
	ER			-0.078***	-5.366	-0.107	-0.05
	Anxiety			0.502***	38.173	0.476	0.528
Equation 4							
Insomnia	IA	0.126	132.544***	0.119***	27.305	0.11	0.127

Note: All variables in the model were entered into the regression equation after standardization. *** *p* < 0.001

Table 4 Results and comparison of chain mediating effect (*n* = 7353)

	β	SE	Boot LLCI	Boot ULCI	Ratio of indirect to total effect	Ratio of indirect to direct effect
Total effect	0.119	0.004	0.11	0.127	-	-
Direct effect	0.038	0.004	0.03	0.047	-	-
Total indirect effect	0.08	0.003	0.074	0.087	67.23%	210.53%
Ind1	0.013	0.003	0.008	0.018	10.92%	34.21%
Ind2	0.029	0.002	0.024	0.033	24.37%	76.32%
Ind3	0.039	0.002	0.035	0.043	32.77%	102.63%

Note: Ind1:IA-> ER-> Insomnia; Ind2: IA -> Anxiety-> Insomnia; Ind3: IA -> ER -> Anxiety-> Insomnia
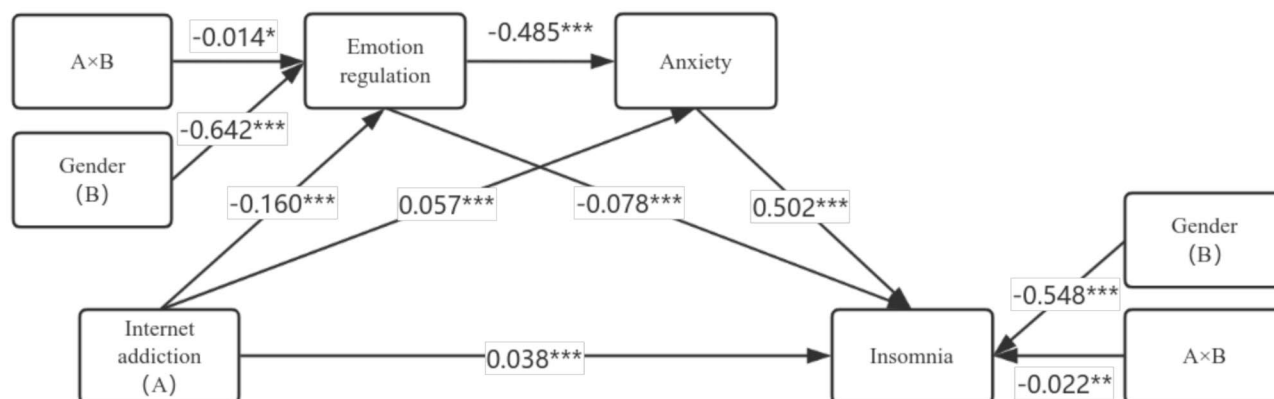
Fig. 2 Diagram of Moderated Mediation Effect

Discussion

As far as we know, this study is the first to explore the relationships among IA, ER, anxiety, and insomnia among freshmen under different gender conditions. We examined the potential mechanisms and interactions among these factors through the Process plugin. We found that IA, anxiety, and insomnia are positively correlated with each other, while ER is negatively correlated with IA, anxiety, and insomnia. IA can positively predict the level of insomnia. ER and anxiety play a chain - mediating role between IA and insomnia, and gender plays a moderating role. This study opens a new door to the exploration of IA and insomnia among college students.
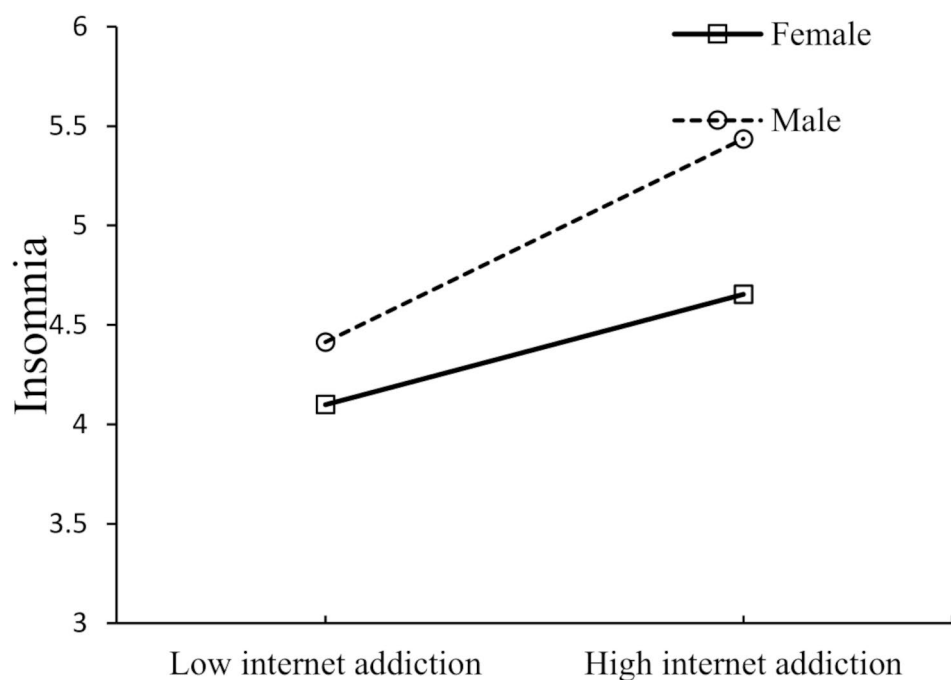
IA and insomnia

Consistent with previous findings [49], our results revealed a significant positive correlation between IA and insomnia severity among college freshmen, and IA was a negative predictor of insomnia (H1).

As college freshmen have just come to a new college environment and left their families and familiar friends, a new social support system has not yet been established while their former social support has weakened. There is research indicating that social support has a significant negative impact on the IA of college freshmen [50]. This age group is particularly sensitive to social media, keeping up with the trends, and online communication. During the process of establishing new social support,

Table 5 Analysis of moderated mediation

Outcome variable	Predictive variable	R^2	F	β	t	LLCI	ULCI
ER		0.287	295.789***				
	IA			-0.16	-47.145***	-0.166	-0.153
	Gender			-0.642	-8.921***	-0.783	-0.501
	Int1			-0.014	-2.151*	-0.027	-0.001
Anxiety		0.332	404.673***				
	IA			0.057	14.769***	0.05	0.065
	ER			-0.485	-41.501***	-0.508	-0.462
Insomnia		0.322	290.798***				
	IA			0.037	8.351***	0.028	0.046
	ER			-0.089	-6.059***	-0.117	-0.06
	Anxiety			0.502	38.29***	0.476	0.528
	Gender			-0.548	-6.700***	-0.708	-0.388
	Int1			-0.022	-2.952**	-0.036	-0.007

Note: All variables in the model were entered into the regression equation after standardization. Int1: IA × Gender. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$
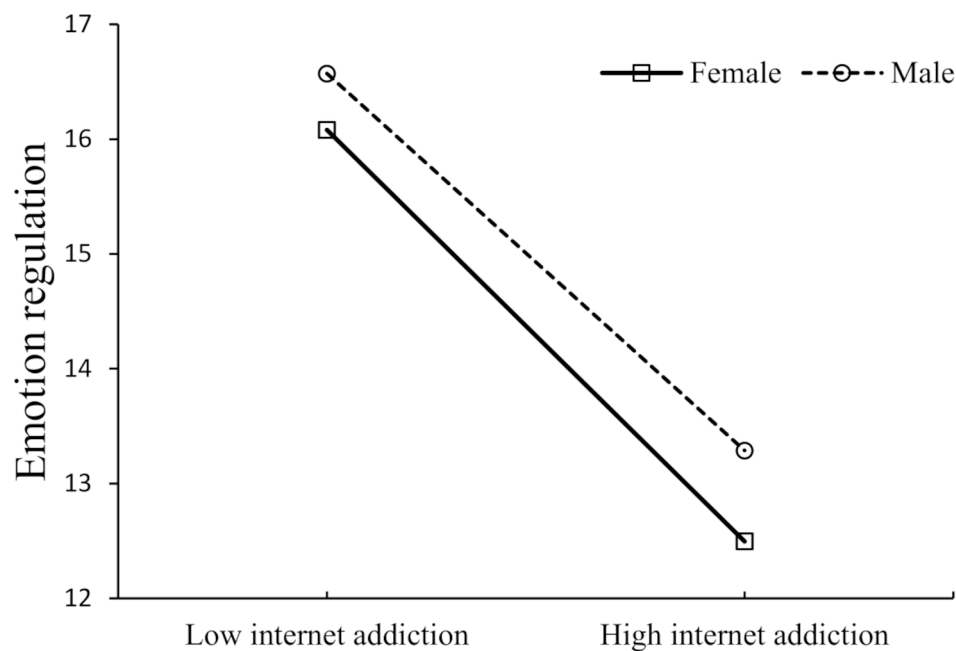

Fig. 3 Simple slope plots
The moderating role of gender in the relationship between IA and insomnia

college freshmen usually use social media as the main means of communication [51]. Additionally, they are at a crucial stage of rapid development and change in brain neurology, as are identity exploration and the transition to adulthood [52]. After escaping the pressure of college entrance exams and relatively strict family discipline, they may spend more free time engaging in activities such as browsing social media, watching online videos, or playing games [53]. Therefore, college freshmen are more likely to develop internet addiction.

IA may lead to serious cognitive dysfunction and psychological problems [54], and IA increases depression and anxiety levels among college freshmen [55]. On a physical level, IA is associated with musculoskeletal pain, and excessive internet use is associated with an increased risk of neck, shoulder, and lower back pain among college freshmen, with severe addiction significantly increasing these risks [56]. Academically, IA negatively impacts student performance by reducing self-esteem, self-confidence, and academic self-efficacy. At the sociocultural level, it can also intensify feelings of loneliness and a sense of poor social skills, thus impeding students from participating effectively in academic and social activities [57]. In today's technologically advanced society, surfing the Internet before bedtime has become a habit among young people. This corresponds to the third insomnia

Fig. 4 Simple slope plots
The moderating role of gender in the relationship between IA and ER

Table 6 Moderation effect across gender

Effects		β	SE	LLCI	ULCI
Direct Effect	Male	0.048	0.006	0.037	0.059
	Female	0.026	0.006	0.014	0.037
Indirect Effect 1	Male	0.014	0.002	0.009	0.018
	Female	0.015	0.003	0.01	0.02
Indirect Effect 2	Male	0.037	0.002	0.033	0.041
	Female	0.041	0.002	0.037	0.045

Note: Indirect 1: IA-> ER-> Insomnia. Indirect 2: IA -> ER -> Anxiety-> Insomnia

theoretical model mentioned above, where using the Internet before sleep, as a behavior that perpetuates insomnia, affects sleep. These multiple dilemmas ultimately affect the quality of sleep and increase the severity of insomnia among college freshmen.

Notably, the total effect of IA in predicting insomnia in this study was 11.9%, which is lower than that reported in previous findings (22.1%) [58]. This may be because the factors affecting insomnia include a wide range of biological, psychological, and social environmental factors, and although IA is an important factor affecting insomnia, it is part of a wider range of influences [59].

In summary, the "multi - dimensional causes" of insomnia among freshmen suggest that when intervening in IA, we need to consider both behavior modification and the reconstruction of social support. For example, through offline social activity guidance, time management training, and pain prevention education, we can reduce the combined physical and mental harm caused by addictive behaviors.

IA, ER, anxiety and insomnia

The present study demonstrated that part of the association between IA and insomnia is mediated by ER and anxiety (H2), which may reveal the psychiatric mechanisms underlying how IA indirectly affects the severity of insomnia among college freshmen.

Some research indicates that there is a certain connection between IA and cognitive reappraisal. Cognitive reappraisal is one of the two commonly used strategies for ER. It occurs in the initial stage of the emotion - generation process, which is crucial for effectively understanding and managing emotions. IA can impair this cognitive process, making it difficult for people to accurately assess their emotions, leading to inappropriate emotional reactions or an exacerbation of emotional distress [60]. IA was negatively correlated with well-being and positively correlated with aggression, a link mediated solely by ER [61]. Similarly, in adolescents with anxiety disorders during the COVID-19 outbreak, IA exacerbates trauma reactions and anxiety, with ER playing a mediating role [62].

Physiologically, IA is associated with changes in the autonomic nervous system similar to those observed in drug addiction. The sympathetic nervous system becomes more reactive, resulting in an increased heart rate and respiratory response, which are physiological markers of anxiety [63]. This enhanced sympathetic activity exacerbates the anxiety experienced by people with IA [64]. In addition, altered brain connectivity, disruption of the psychological contract, and stress-induced anxiety all

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contribute to the complex interactions between IA and anxiety [65, 66]. This finding is consistent with our findings that IA can directly affect anxiety levels as well as indirectly by reducing ER.

It is worth noting that some studies have also pointed out that anxiety is generally associated with an increased level of IA [67, 68]. Anxiety is considered a key risk factor for IA [69]. In addition, studies have found that anxiety plays a significant mediating role between various factors and IA [70, 71]. Similarly, longitudinal studies have also found that anxiety is an important predictor of IA [72]. The compensatory Internet use theory suggests that individuals often turn to the Internet for self-regulation when experiencing negative impacts [73]. Based on this, we believe that anxiety and IA seem to influence each other. In subsequent studies, we will continue to explore in depth the bidirectional predictive effects of IA and anxiety in the mediating model.

College freshmen with ER difficulties and anxiety symptoms suffer from increased stress, and neurobiologically, insomnia may impair neuroplasticity and stress immune pathways in the brain, making sleep quality more challenging for college freshmen [74]. Additionally, anxiety can interfere with sleep through enhanced cognitive and physiological arousal, which can lead to difficulty falling and staying asleep [75]. Similarly, anxiety fully mediates the relationship between mood dysregulation and insomnia severity in patients with alcohol use disorders, suggesting that anxiety symptoms constitute a key pathway through which mood dysregulation leads to sleep disturbances [76]. This finding is consistent with our findings.

In summary, we have found that the chain - mediating role of ER difficulties and anxiety between IA and insomnia reveals the transmission path of the psychological mechanism. This provides a clear target for psychological intervention. By improving the ability of ER, it may be possible to break the vicious cycle of "addiction - anxiety - insomnia".

Moderating effect of gender

This study also examined whether gender moderates the relationship between IA and insomnia severity among college freshmen. The results revealed that IA among female freshmen was more likely to negatively affect ER, which increased anxiety levels and increased insomnia severity, and that males were at greater risk of experiencing increased insomnia severity than females were as the severity of IA increased (H3).

In men, there is sex specificity in the functional connectivity between some brain regions that are strongly associated with sleep disorders [77]. Compared with females, males typically exhibit greater levels of compulsive internet use, which is associated with poorer sleep quality, especially in the 18–35 years age group [78, 79]. Excessive screen blue light exposure is common in individuals with IA and can interfere with melatonin production and circadian rhythms, thereby affecting sleep quality in both men and women [80]. However, the extent of these effects may vary. In terms of visual processing, studies using functional brain imaging have shown that men are much more responsive to blue light in the primary visual cortex, showing higher luminance perception and greater sustained attention under blue-rich light conditions, which are associated with increased frontal NREM sleep slow-wave activity following blue light exposure [81, 82].

Women may be more susceptible to the emotional and psychological aspects of internet use, which can lead to more severe sleep disorders [83]. In terms of internet usage habits, female IAs are more inclined toward social media dependency [84]. Women with IA typically have higher rates of psychiatric comorbidities, such as mood disorders, anxiety, and obsessive−compulsive disorder, and tend to exhibit personality traits such as impulsivity, novelty-seeking, and self-transcendence more frequently than men do [85]. In addition, women show reduced connectivity between anticipatory and negative emotion networks, which is associated with maladaptive ER strategies [33], suggesting that women may experience more difficulties in ER in the context of IA. At the same time, neurophysiological studies using event-related potentials suggest that women show stronger early emotional responses to negative stimuli and that this increased reactivity may contribute to the increased prevalence of anxiety and mood disorders in women [86]. These processes may influence and reinforce each other's interactions: compared with female freshmen, male freshmen have a more pronounced degree of insomnia that is affected by IA. The greater the risk of IA among female freshmen is, the more pronounced the decrease in ER, which leads to the onset of anxiety, and the increase in anxiety affects their ability to fall asleep and maintain their sleep, ultimately leading to increased severity of insomnia.

In conclusion, this study highlights the important role of gender differences. It emphasizes that in the mental health education of college students, differential intervention measures should be formulated according to gender. For male students, efforts can be focused on guiding them to arrange their Internet usage time reasonably, reducing the direct impact of IA on sleep. For female students, it is necessary to strengthen the cultivation of their emotion - regulation abilities, helping them cope with the emotional fluctuations brought about by IA, thus reducing the risks of anxiety and insomnia.

Limitations and future studies

This study has several limitations that need to be considered in future studies. First, most of the assessment tools in this study were derived from self-reports, and consideration should be given to including more objective assessment tools to reduce subjective influences.

Second, the cross-sectional design prevented us from making causal inferences. The next step will be to use a longitudinal study to explore the causal relationship and mechanism of action between IA and insomnia.

Third, although the subjects in this study were all college freshmen from various colleges, only students from one university were involved. In the future, other schools should be included in multicentre analyses to further explore this relationship.

Fourth, there may be other potential influencing factors that have not been included in the study, such as parenting styles, peer influence, school environment, and the nature of online content.

This study not only provides a theoretical basis for mental health interventions among college students but also reflects the social challenges in the era of technology dependence. The association between IA and insomnia is essentially a microcosm of the conflict between digital lifestyles and human physiological and psychological needs. Future research could further explore how families, schools, and social policies can collaborate to build a "low - addiction environment", such as optimizing curriculum design to reduce online dependence and promoting sleep - friendly dormitory management.

Conclusion

This study explored the relationships among internet addiction, emotion regulation, anxiety, and insomnia among freshmen under different gender conditions. It was found that there are close connections and gender differences among these factors. There is a significant positive correlation among internet addiction, anxiety, and insomnia, while emotion regulation is negatively correlated with internet addiction, anxiety, and insomnia. Internet addiction has a positive predictive effect on the level of insomnia. Emotion regulation and anxiety play a chain - mediating role between internet addiction and insomnia, and gender plays a moderating role in this relationship. These findings provide a new perspective for understanding the problems of internet addiction and insomnia among freshmen, but they still need to be further verified and expanded in more studies.

Abbreviations
IA	Internet addiction
ER	Emotion regulation
IAT	Internet Addiction Test
GAD-7	Generalized Anxiety Disorder-7
ISI	Insomnia Severity Inventory

Declarations

Ethics approval and consent to participate
The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by t he Ethics Committee of Jingzhou Mental Health Centre (NO. 2024LL0801). At the same time, informed consent was obtained from all subjects in declaration section.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not Applicable.

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