Article

Sleep Disturbance Mediates the Relationship between Problematic Technology Use and Psychotic-Like Experiences: A Large Cross-Sectional Study in 87,302 Chinese Adolescents

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ABSTRACT

Background: This study of 87,302 Chinese adolescents aimed to test: (1) the association of psychotic-like experiences (PLEs) with sleep disturbance and three different subtypes of problematic technology use (PTU), including problematic social media use (PSMU), problematic smartphone use (PSU), and internet gaming disorder (IGD); and (2) whether sleep disturbance mediated the relationship between PTU and PLEs.

Method: 16-item Prodromal Questionnaire, Smartphone-Application Based Addiction Scale, the Bergen Social Media Addiction Scale, the Internet Gaming Disorder Scale-Short Form, Pittsburgh Sleep Quality Index, and Strength and Difficulties Questionnaires were employed.

Results: (1) The prevalence of clinically relevant PLEs, IGD, PSMU, PSU, and sleep disturbance was 18.1%, 2.4%, 1.5%, 17.2%, and 26%, respectively. (2) PSU, PSMU, and IGD displayed comparable levels of association with PLEs (r = 0.37–0.41) and sleep disturbance (r = 0.42–0.47); (3) Sleep disturbance acted as a partial mediator between PTU and PLEs, mediating 51.8% of the effect of PSU, 49.2% of the effect of PSMU, and 44.1% of the effects of the IGD on PLEs.

Conclusion: PTUs are closely associated with sleep disturbance and PLEs. The results call for formal assessments for sleep disturbance and PLEs among adolescents with PTU. Furthermore, targeting sleep disturbance holds great promise for the prevention and treatment of PLEs among adolescents, particularly those with PTUs.

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KEYWORDS: psychotic-like experience; problematic smartphone use; problematic social media use; internet gaming disorder; sleep disturbance

INTRODUCTION

Psychotic-like experiences (PLEs) refer to symptoms and experiences (e.g., perceptual anomalies, delusional thoughts, and disorganized thinking) that resemble those seen in clinical psychosis, such as schizophrenia [1]. PLEs are highly prevalent and distressing in adolescents and young adults [1–3]. A meta-analysis suggests that 25% of high school and college students report lifetime PLEs [4]. In China, a recent large-scale study found that 16% of 67,538 adolescents reported frequent PLEs within the last month [1]. Although PLEs themselves are not inherently pathological, they are closely associated with a range of adverse outcomes in adolescents such as depression [5], anxiety [6], self-injury [7], sleep disturbances [3], and suicide [7–9]. Longitudinal studies further establish that PLEs during adolescence can predict the subsequent onset of schizophrenia [10]. These studies underscore the strong need to determine the potential risk factors for PLEs in adolescents, which might contribute to the early identification and timely interventions for PLEs.

Problematic Technology Use as a Potential Risk Factor for PLEs among Adolescents

Problematic technology use (PTU) could be a potential risk factor for PLEs, which has attracted increasing attention in recent years [11,12]. PTU refers to the overuse of technology that impairs mental well-being and function [13]. It is an umbrella term covering both generalized (e.g., problematic internet use (PIU) or problematic smartphone use (PSU)) and specific (e.g., problematic social media use (PSMU), internet gaming disorder (IGD)) conditions. A recent meta-analysis demonstrates that one-fourth of the global population could be affected by PTU [14].

In 2012, case reports first noted that adolescents experienced PLEs following internet withdrawal or prolonged internet use [15,16]. In the next year, Mittal et al. provided early large-scale epidemiological evidence, finding a positive relationship between PLE severity and PIU among 170 young individuals [17]. They concluded that PIU might be a new environmental risk factor for PLEs. Subsequent studies across various cultures confirmed the positive correlation between PTU and PLEs [11,12,18,19]. Additionally, these studies found associations between PTU and conditions such as schizotypal personality disorder, ultra-high-risk psychosis, and both prodromal and clinical schizophrenia [20–24]. These findings strongly indicate a close relationship between PLEs and PTU. Table 1 summarizes the existing literature on the connection between PLEs and PTU.

Table 1. Previous studies on the positive associations between PTU and PLEs.

Study	Country/region	Sample characteristics	Mean age	Types of PTU	Sample size
Mittal et al., 2013 [17]	America	College students	19.1	PIU	170
Lee et al., 2019 [11]	Korea	High school students	18.6	PIU	1678
Fekih-Romdhane et al., 2020 [19]	Tunisia	College students	21.9	PSMU	1007
McMahon EM et al., 2021 [12]	Europe	Adolescents	14.73	PIU	973
Amendola et al., 2023 [25]	Italy	Emerging adults	24.68	PIU	238
Fekih-Romdhane et al., 2023 [18]	Tunisia	Emerging young adults	21.91	PSU	4158
Fekih-Romdhane et al., 2023 [26]	Tunisia	College students	21.26	IGD	851

Note: PIU: problematic internet use; PSMU: problematic social media use; PTU: problematic technology use; PSU: problematic smartphone use; IGD: internet gaming disorder; PLEs: psychotic-like experiences.

However, several notable knowledge gaps exist. First, most studies have primarily focused on PIU, with limited research on other subtypes of PTU, such as PSU, PSMU, and IGD. It remains unclear whether these different subtypes are associated with PLEs and whether these associations vary in strength. Second, previous research has predominantly involved college students or emerging adults [18,21], neglecting the high-risk period of adolescence for experiencing PLEs [27]. To our knowledge, only two studies assessed the association between PTU and PLEs in adolescents [11,12]. Third, previous studies have often had moderate sample sizes, generally below 1000 participants. Fourth, the mechanisms underlying the link between PTU and PLEs remain largely unexplored. Finally, despite growing interest in the association between PTU and PLEs, no epidemiological evidence is available for Chinese adolescents. A large-scale study is needed to provide robust and comprehensive evidence of the association between different types of PTU and PLEs in Chinese adolescents and to elucidate potential mechanisms.

Sleep Disturbance as a Potential Mediator between PTU and PLEs

One potential pathway linking PTU to PLEs is sleep disturbance. Longitudinal studies have consistently reported that PTU predicts sleep disturbances [28], and that sleep disturbance is a well-established risk factor for later PLEs [29,30], thus supporting the potential PTU-sleep disturbance-PLEs pathways. Furthermore, prior research indicates that sleep disturbance is a common bridge linking PTUs to its related adverse consequences, such as depression, suicide, and compromised physical health [31–34]. Therefore, it is plausible that sleep disturbance might be a potential mediator between PTU and PLEs. However, few empirical studies have explored this relationship. To our knowledge, only one recent study among 851 college students (mean age of 21.26 years) revealed a

partial mediating role of insomnia between IGD and paranoid ideation [26]. Despite this primary evidence, the study focused solely on insomnia and IGD and involved a relatively small sample of college students. A large-scale study in adolescents, capturing a broad range of sleep disturbances and PTU, is warranted.

The Current Study

The present study aims to investigate the relationships among PLEs, sleep disturbances, and the three most prevalent subtypes of PTU (i.e., IGD, PSU, PSMU) in a large sample of Chinese adolescents. We hypothesize that: (1) PLEs will be positively associated with PTU and sleep disturbances; and (2) sleep disturbances will mediate the relationship between PTU and PLEs.

METHODS

Participants and Study Procedure

The present school-based study was conducted in Zigong, a city located in the southern region of Sichuan, China, from September to December 2020. The city consists of four districts and two counties, and two districts and one county were selected for participation through cluster sampling. Students in grade 5 and above from all elementary, junior high, and senior high schools within the selected areas were invited to participate. To ensure survey validity, investigators and school head teachers received training on the survey process and questionnaire. Their responsibilities included introducing the study's purpose, addressing students' questions as needed, and overseeing the survey administration. The questionnaire was administered electronically, and participants completed it in the computer rooms of the selected schools. Participation in the study was voluntary, and all participants and their legal guardians provided informed consent before the survey. The study protocol was reviewed and approved by BLIND FOR REVIEW.

Measurements

Basic information

We collected the following demographic information through self-designed questionnaires: age, sex, school type (junior high/senior high), residence (urban/country/town), family type (nuclear/single-parent/remarried), only child (yes/no), left-behind children (yes/no), current drinking status, and current smoking status.

Psychotic-like experience

We utilized the Chinese version of the 16-item Prodromal Questionnaire (PQ-16) to assess PLEs. PQ-16 is a validated self-reported questionnaire for PLEs in adolescents [35,36]. It consists of three subscales: perceptual abnormalities/hallucinations (9 items), unusual thought

content/delusional ideas/paranoia (5 items), and negative symptoms (2 items) [37]. The rating of PQ-16 involves two steps. First, participants report whether they have PLEs within the last month. Those who responded affirmatively were then requested to rate the level of distress associated with their PLEs using a 4-point Likert scale, ranging from 0 (not at all) to 3 (severe distress). The total scores of PQ-16 range from 0–48, with higher scores indicating more severe PLEs and associated distress. The Chinese version of PQ-16 has demonstrated high psychometric properties [37,38]. A cutoff point of 9 was applied to determine participants who had experienced clinically relevant PLEs [38].

Sleep disturbance

Pittsburgh Sleep Quality Index (PSQI) was employed to evaluate sleep disturbance [39]. It consists of 19 items, grouped into 7 factors. The total scores of PSQI ranged from 0–21. Following a previous study [39], a cutoff point of 6 indicated the presence of sleep disturbance.

Problematic technology use

We used the Smartphone-Application Based Addiction Scale (SABAS) to measure PSU, the Bergen Social Media Addiction Scale (BSMAS) to assess PSMU, and the Internet Gaming Disorder Scale-Short Form (IGDS9-SF) to measure IGD. Previous studies have confirmed their excellent validity and reliability in the Chinese population [40]. The total scores ranged from 9–45 for IGDS9-SF, 6–30 for BSMAS, and 6–36 for SABAS. Following previous studies [41–44], a cutoff point of 32 for IGDS9-SF, 24 for BSMAS, and 23 for SABAS was utilized to identify IGD, PSMU, and PSU.

Internalizing and externalizing problems

We assessed the internalizing and externalizing problems via the self-reported version of Strength and Difficulties Questionnaires (SDQ) [45,46]. The questionnaire includes 25 items and four difficulty factors (emotional symptoms, conduct problems, hyperactivity/inattention, and peer relationship problems), and one strength factor (pro-social behavior). SDQ applied a three-point Likert scale and participants rated their experiences from 0 (Not like me) to 2 (Very like me). The total difficulty scores were calculated by summing up the scores of the sum of the four difficulty factors. Higher scores in the difficulty factor indicated more severe internalizing and externalizing problems.

Statistical Analysis

Continuous data were presented as mean and standard deviation (SD), while categorical data were reported as frequency and percentage. First, we compared the inter-group differences between adolescents with and without clinically relevant PLEs via Chi-square tests and student t-tests as appropriate. Effect sizes were calculated for continuous data and t-tests

using Cohen's d, with values below 0.5 indicating a small effect, between 0.5 and 0.8 indicating a medium effect, and above 0.8 indicating a large effect. To account for multiple testing, Bonferroni corrections were applied (p' = 0.05/23 = 0.0021).

Second, we performed a stepwise logistic regression analysis to identify the independent association between PTU, sleep disturbance, and PLEs. Demographic variables and mental health problems that demonstrated statistical significance in the univariate analysis were included as independent variables.

Third, we conducted the Spearman correlation between PSQI, SABAS, BSAMS, IGDS9-SF, and PQ-16 as well as its subscales. Following a previous study [47], the strength of their association was interpreted according to correlation coefficients: $0.1 < |r| < 0.3$ indicated a small correlation, $0.3 < |r| < 0.5$ indicated a moderate correlation, and $|r| > 0.5$ indicated a large correlation.

Finally, we conducted a mediation analysis to examine the hypothesis that sleep disturbance mediated the relationship between PTUs and PLEs. Demographic information (sex, age, school type, family type, current drinking and smoking status, left-behind children, and only children) was controlled as covariates. We employed Model 4 in the PROCESS procedure of Statistical Package for the Social Sciences (SPSS) version 27.0. Bootstrap sampling was performed 5000 times to generate 95% confidence intervals (CI). All statistical analyses were conducted using SPSS. The tests were two-tailed, and statistical significance was set at $p < 0.05$.

RESULTS

Sample Characteristics

A total of 90,039 adolescents from 130 schools were recruited for the study. Among them, 87,302 participants (43,829 girls and 43,473 boys) provided complete responses (Table 2), resulting in a high response rate of 97%. The sample consisted of students from elementary schools (29%, n = 25,460), junior high schools (48%, n = 42,185), and senior high schools (23%, n = 19,657). The mean age of the participants was 13.37 years old. Approximately one-fourth of the participants were only children (24%, n = 20,659), and one-third were left-behind children (34%, n = 29,280). The majority of the participants lived in urban areas (60%, n = 52,122) and belonged to nuclear families (79%, n = 68,811). A small proportion of the participants were current smokers (1.3%, n = 1127) and drinkers (8.9%, n = 7745). The prevalence of clinically relevant PLEs, IGD, PSMU, PSU, and sleep disturbance was 18.1% (n = 15, 837), 2.4% (n = 2060), 1.5% (n = 1301), 17.2% (n = 15, 449), and 26% (n = 23,024), respectively.

Table 2. Sample characteristics of adolescents with and without PLEs.

Variables	Overall, *n* = 87,302 [1]	Without PLEs, *n* = 71,465 [1]	With PLEs, *n* = 15,837 [1]	*p*-value [2]	Cohen's D
Gender				0.4	
Female	43,829 (50%)	35,834 (50%)	7995 (50%)		
Male	43,473 (50%)	35,631 (50%)	7842 (50%)		
School				<0.001	
Elementary School	25,460 (29%)	21,137 (30%)	4323 (27%)		
Junior high school	42,185 (48%)	33,719 (47%)	8466 (53%)		
Senior high school	19,657 (23%)	16,609 (23%)	3048 (19%)		
Age, year	13.37 (2.10)	13.38 (2.13)	13.29 (1.96)	<0.001	−0.045
Current smoker, yes	1127 (1.3%)	608 (0.9%)	519 (3.3%)	<0.001	
Current drinker, yes	7745 (8.9%)	4761 (6.7%)	2984 (19%)	<0.001	
Residence				0.009	
Urban	30,661 (35%)	25,259 (35%)	5402 (34%)		
Country	35,180 (40%)	28,660 (40%)	6520 (41%)		
Town	21,461 (25%)	17,546 (25%)	3915 (25%)		
Only child, yes	20,659 (24%)	16,620 (23%)	4039 (26%)	<0.001	
Left-behind Child, yes	29,280 (34%)	23,601 (33%)	5679 (36%)	<0.001	
Family status				<0.001	
Nuclear	68,811 (79%)	57,191 (80%)	11,620 (73%)		
Single-parent	11,811 (14%)	9204 (13%)	2607 (16%)		
Remarried	6680 (7.7%)	5070 (7.1%)	1610 (10%)		
Emotional Symptoms	2.87 (2.46)	2.34 (2.11)	5.29 (2.47)	<0.001	1.35
Conduct Problems	2.20 (1.59)	1.96 (1.44)	3.29 (1.78)	<0.001	0.88
Hyperactivity Inattention	3.47 (2.23)	3.12 (2.09)	5.04 (2.15)	<0.001	0.92
Peer problems	3.25 (1.59)	3.09 (1.50)	3.99 (1.74)	<0.001	0.58
Prosocial behaviors	7.40 (2.12)	7.52 (2.09)	6.86 (2.16)	<0.001	-0.31
SDQ total Difficulties	11.8 (5.8)	10.5 (5.0)	17.6 (5.5)	<0.001	1.39
IGDS9SF	14.7 (6.4)	13.6 (5.5)	19.3 (8.0)	<0.001	0.95
BSMAS	10.2 (4.6)	9.5 (4.1)	13.3 (5.6)	<0.001	0.86
SABAS	15 (7)	14 (6)	20 (7)	<0.001	0.82
PSQI	3.9 (3.2)	3.2 (2.7)	6.8 (3.5)	<0.001	1.25

Note: [1] n (%), Mean (SD). [2] Pearson's Chi-squared test, Welch Two Sample t-test. PLE: psychotic-like experience; SABAS: smartphone application-based addiction scale; BSAMS: Bergeon social media addiction scale; IGDS9-SF: Internet gaming disorder scale-short form; PSQI: Pittsburgh Sleep Quality Index; PQ-16: 16-item Prodromal Questionnaire.

Comparison between Adolescents with and without PLEs

Table 2 displayed the difference in demographic information, problematic technology use, sleep disturbance, and mental health between adolescents with and without PLEs. We found no significant sex difference in PLEs. They were more likely to be junior high school students, left-behind children, only children, current drinkers, and current smokers. They also had a higher likelihood of belonging to a non-nuclear family. These associations between PLEs and demographic information remained significant after Bonferroni Correction.

Adolescents with clinically relevant PLEs exhibited significantly worse mental health and problematic internet use compared to those without. They had higher scores on the SDQ subscales, indicating more emotional problems (5.29 vs 2.34), conduct problems (3.29 vs 1.96), hyperactivity/inattention (5.04 vs 3.12), and peer problems (3.99 vs 3.09). Additionally, they reported lower levels of prosocial behavior (6.86 vs 7.52). The prevalence of IGD (8.0% vs 1.1%), PSMU (5.1% vs 0.7%), PSU (41% vs 12%), and sleep disturbance (61% vs 19%) was significantly higher in adolescents with clinically relevant PLEs. These associations remained significant after Bonferroni correction. The effect sizes, as indicated by Cohen's d, for all these variables except the SDQ-peer problem subscale and SDQ-prosocial subscale exceeded 0.8, suggesting a very large effect size.

Association between Problematic Internet Use, Sleep Disturbance, and PLEs

In the unadjusted model, the presence of PSU, PSMU, IGD, and sleep disturbance increased the risk of PLEs by 4.15, 7.54, 7.80, and 6.96 times, respectively (Table 3). After further adjusting for demographic information (age, school type, family type, current drinking and smoking status, left-behind children, and only children) and mental health problems (SDQ scores), PSU (OR, 1.58, 95%CI, 1.41–1.78), PSMU (OR, 1.38, 95%CI, 1.20–1.59), IGD (OR, 1.58, 95%CI, 1.41–1.78), and sleep disturbance (OR, 2.87, 95%CI, 2.78–2.99) remained independently associated with PLEs (all $p < 0.001$).

Table 3. Association of PSU, PSMU, IGD, and sleep disturbances with PLEs.

Variable	Without PLE, *n* = 71,465	With PLE, *n* = 15,837	Crude OR [1]	*p*-value	Adjusted OR [2]	*p*-value
PSU	9163 (12%)	6286 (41%)	4.15 (4.00, 4.32)	<0.001	1.35 (1.29, 1.42)	<0.001
PSMU	501 (0.7%)	800 (5.1%)	7.54 (6.73, 8.44)	<0.001	1.38 (1.20, 1.59)	<0.001
IGD	790 (1.1%)	1270 (8.0%)	7.80 (7.12, 8.54)	<0.001	1.58 (1.41, 1.78)	<0.001
Sleep disturbance	13,298 (19%)	9726 (61%)	6.96 (6.71, 7.22)	<0.001	2.87 (2.75, 2.99)	<0.001

Note: [1] OR: Odds ratio. [2] Adjusted for demographic information (age, school type, family type, current drinking and smoking status, left-behind children, and only children) and mental health problems (SDQ scores). PSU: problematic smartphone use; PSMU: problematic social media use; IGD: internet gaming disorder; PLE: psychotic-like experience.

Table 4 presented the Spearman correlation between SABAS, BSAMS, IGDS9-SF, PSQI, and PQ-16 subscales and total scores. There was a comparable level of association between the total and subscale scores of PQ-16 and the scores of SABAS, BSAMS, and IGDS9-SF (r range: 0.37 to 0.41). PSQI exhibited a substantial association with PQ-16 scores (r = 0.53) (all $p < 0.001$).

Sleep Disturbance Mediated the Relationship between PSU, PSMU, IGD, and PLEs

Table 5 described the mediation effects of sleep disturbances on the association between PTU and PLEs. The 95% bootstrapped CI of the indirect effect of PSU, PSMU, and IGD on PLEs via sleep disturbance did not include zero, indicating that sleep disturbance was a partial mediator between PTU and PLEs. Specifically, sleep disturbance mediated 51.8% of the effect of PSU, 49.2% of the effect of PSMU, and 44.1% of the effects of the IGD on PLEs.

Table 4. Spearman correlation between SABAS, IGDS9-SF, BSAMS, PSQI, and PQ-16.

Variables	BSMAS	SABAS	IGDS9-SF	PQ-16	PSQI	Negative	Unusual thought	Perceptual abnormalities
BSMAS	--							
SABAS	0.573***	--						
IGDS9-SF	0.490***	0.623***	--					
PQ-16	0.375***	0.366***	0.407***	--				
PSQI	0.470***	0.466***	0.417***	0.532***	--			
Negative	0.322***	0.346***	0.327***	0.726***	0.426***	--		
Unusual thought	0.354***	0.382***	0.383***	0.915***	0.505***	0.591***	--	
Perceptual abnormalities	0.330***	0.341***	0.369***	0.887***	0.477***	0.562***	0.749***	--

Note: ***$p < 0.001$. SABAS: smartphone application-based addiction scale; BSAMS: Bergeon social media addiction scale; IGDS9-SF: Internet gaming disorder scale-short form; PSQI: Pittsburgh Sleep Quality Index; PQ-16: 16-item Prodromal Questionnaire.

Table 5. Mediation analysis: direct and indirect effects of PSU, PSMU, and IGD on PLEs, taking sleep disturbance as the mediator.

Variables	PIU-PSQI		Total effect		Direct effect		Indirect effect		Proportion mediated %
	B	95% CI	B	95% CI	B	95% CI	B	Corrected 95% CI	
SABAS	0.189***	0.186–0.191	0.359***	0.352–0.365	0.173***	0.167–0.179	0.186	0.181–0.190	51.8%
BSAMS	0.278***	0.274–0.283	0.551***	0.542–0.560	0.280***	0.271–0.289	0.271	0.264–0.279	49.2%
IGDS9SF	0.197***	0.194–0.200	0.422***	0.416–0.429	0.236***	0.223–0.243	0.186	0.181–0.191	44.1%

Note: PSU: problematic smartphone use; PSMU: problematic social media use; IGD: internet gaming disorder; PLE: psychotic-like experience; SABAS: smartphone application-based addiction scale; BSAMS: Bergeon social media addiction scale; IGDS9-SF: Internet gaming disorder scale-short form.

DISCUSSION

This is the first large-scale study to: (1) determine the association of PLEs with PSU, PSMU, and IGD; (2) determine the mediation role of sleep disturbance in their association in a substantial sample of Chinese adolescents (*n* = 87,302). The major findings included: (1) The prevalence of clinically relevant PLEs, IGD, PSMU, PSU, and sleep disturbance was 18.1% (*n* = 15,837), 2.4% (*n* = 2060), 1.5% (*n* = 1301), 17.2% (*n* = 15,449), and 26% (*n* = 23,024), respectively. (2) Adolescents with PLEs demonstrated much higher PTU, mental distress, and sleep disturbance. PSU, PSMU, and IGD displayed comparable levels of association with PLEs (r = 0.37–0.41) and sleep disturbance (r = 0.42–0.47); (3) Sleep disturbance was a partial mediator between PTUs and PLEs, mediating 51.8% of the effect of PSU, 49.2% of the effect of PSMU, and 44.1% of the effects of the IGD on PLEs.

The Direct Effect of PTU on PLEs

Consistent with our first hypothesis, we found adolescents with clinically relevant PLEs demonstrated much higher PTU. Interestingly, PLEs showed similar levels of association with the three subtypes of PTU (r = 0.36–0.41), closely matching the strength of association between PLEs and PIU found in previous studies [11,25]. For example, Lee et al. found that PIU (assessed by Korean Scale for Internet Addiction) exhibited a moderate positive association (r = 0.31) with PLEs among Korean adolescents [11]. Another study in Japanese emerging adults found that PTU (assessed by Internet Disorder Scale) was also positively associated with PLEs (r = 0.326) [25]. This similar level of correlation suggests that the negative effects on PLEs are not specific to any particular type of technology use but are likely due to problematic patterns of use in general. Future research should evaluate the association of PLEs with additional subtypes of PTU, such as problematic online shopping, online gambling, and cybersex, to confirm this hypothesis.

The relationship between PTU and PLEs remained significant even after controlling for demographic variables and mental distress, indicating that PTU may be an independent risk factor for PLEs among adolescents. Several explanations could account for this strong association. First, emerging studies suggest that PTU is related to cognitive dysfunction [48], which can interfere with proper information processing and interpretation, directly leading to PLEs. Second, excessive technology use may encroach upon adolescents' sleep and social time [32,33], resulting in sleep disturbances, loneliness, and social withdrawal, indirectly increasing the risk of PLEs. Third, uncontrolled and excessive technology use in adolescents with PTU can lead to real-life losses, such as academic, interpersonal, and functional impairments, contributing to PLEs [43]. Lastly, there might be a bidirectional relationship between PTU and PLEs [49,50]. According to the compensatory internet use model [51], adolescents might overuse technology to escape the distress caused by PLEs. A further longitudinal study is warranted to clarify their causal relationship.

The Indirect Effect of PTU on PLEs through Sleep Disturbance

Consistent with our second hypothesis, we found that sleep disturbance served as a partial mediator between PTU and PLEs, accounting for nearly half of the total effects. Several psychological and biological mechanisms might explain their strong relationship. Excessive use of technology can reduce sleep time, and the blue light emitted from screens can disrupt melatonin secretion and sleep quality. Additionally, stimulating content from games and social media can make it harder to fall asleep [52,53]. Sleep disturbances can promote and maintain PLEs through various mechanisms, such as altering the hypothalamic-pituitary-adrenal axis, causing attention bias, and leading to emotional problems [54].

Our findings aligned with previous research on the mediating role of sleep disturbances between PTU and other adverse psychological outcomes, such as depression and suicidality [31–34]. These consistent results indicated that addressing sleep disturbances might be potential targets for treatment in reducing PTU-related mental distress. Several studies have suggested that limiting internet and smartphone use at night can improve sleep disturbances in adolescents with PSU and PSMU [55,56]. Further research is needed to test the effects of such interventions on PTU-related distress.

Implications of the Study

Our study holds two significant clinical implications. First, it underscores the high incidence of PLEs and sleep disturbances among adolescents with PTU. This finding highlights the importance of timely and regular assessments for sleep distress and PLEs in this population. Second, our study reveals the mediating role of sleep disturbances between PTU and PLEs. Nearly half of the effects of PTU on PLEs were mediated by sleep disturbances. Therefore, targeted interventions addressing sleep disturbances might be effective in reducing PLEs related to PTU.

Strength and Limitations

Our study holds several notable strengths, such as the large sample size, the comprehensive assessments of different subtypes of PTU, and being the first study to uncover the mediating role of sleep disturbance on the association between PLEs and PTU. Despite these strengths, our study has several limitations. First, the cross-sectional study design prohibited us from drawing causal relationships. Second, all measurements were self-reported, which might induce recall and social desirability bias. Third, participants were recruited from one single city in China. Hence, the generalizability of our findings to adolescents in other cultural backgrounds warranted further studies to confirm. Taken together, a further longitudinal, cross-cultural study with more comprehensive assessments is needed to verify our findings.

CONCLUSION

PTU is positively associated with PLEs among Chinese adolescents, with sleep disturbance partially mediating this relationship. Formal assessments of sleep disturbance and PLEs are vital in this vulnerable population. Addressing sleep disturbance holds promise in reducing PTU-related PLEs among adolescents.

ETHICAL STATEMENT

The study procedures were carried out in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of Zigong Mental Health Center [No. 2020–8-01]. Before the start of the survey, participants gave informed consent. Parents' informed consent was also obtained for those younger than 18 years old. This study follows the STROBE guideline.

DATA AVAILABILITY

The dataset of the study is available from the authors upon reasonable request.

AUTHOR CONTRIBUTIONS

Xiaogang Chen contributed to all aspects of the study. Aijun Liao contributed to the analysis and interpretation of data, statistical analysis, and the drafting of the manuscript. Pu Peng contributed to the revision of the manuscript. Zhangming Chen, Youguo Tan and Xiaogang Chen contributed to the study design. Jingguang Li, Aijun Liao, Linlin Zhao, Zhenmei Zhang, Jiaqi Chen, and Youguo Tan contributed to the data acquisition. All authors have reviewed, revised and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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