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Research paper

Chain mediating effect of insomnia, depression, and anxiety on the relationship between nightmares and cognitive deficits in adolescents

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ABSTRACT

Background: The study explored the differences in nightmare, insomnia, depression, anxiety, and cognitive deficits among adolescents and the chain mediating effects of insomnia, depression, and anxiety on the relationship between nightmares and cognitive deficits in adolescents.

Methods: An online survey was used to collect demographic data of 6014 adolescents and assess nightmare, insomnia, depression, anxiety, and cognitive deficits using the Chinese Version of Nightmare Distress Questionnaire, Insomnia Severity Index, Patient Health Questionnaire 9, Generalized Anxiety Disorder 7, and Perceived Deficits Questionnaire-Depression. Spearman correlation analysis and the SPSS function "PROCESS macro" were used for correlation and mediation analyses, respectively.

Results: Female adolescents, senior high school, and poor academic performance had higher nightmare, insomnia, and cognitive deficit scores; those living in the city had higher depression and anxiety scores. Cognitive deficits were positively correlated with nightmares, insomnia, depression, and anxiety. Further, insomnia, depression, and anxiety had a chain mediating effect between nightmares and cognitive deficits in adolescents. Nightmares indirectly affect cognition deficits by affecting insomnia and then depression and anxiety symptoms.

Limitations: As this was a cross-sectional study, the causal relationship between the variables could not be determined. Moreover, reporting bias and volunteer bias might be present.

Conclusions: These findings suggest that clinicians should identify adolescents with frequent nightmares early and provide timely treatment to minimize negative outcomes and possibly limit the chronicity of nightmare disorder. It is significant to maintain the physical and mental health development of adolescents to reduce the risk of insomnia, depression, anxiety, and cognitive deficits.

1. Introduction

Sleep disorders are an important issue affecting the health of adolescents. They impact important daily functions, such as behavior, emotion, learning, and so on, which has aroused widespread concern in society. Adolescents can experience several challenges that can seriously affect their sleep, including physical factors (such as internal circadian delay) and psychological development (such as school load, being ostracized by groups, parents' divorce, etc.) (Dewald et al., 2010). The main symptoms of sleep disorders in adolescents include difficulty falling asleep, difficulty maintaining sleep, early awakening, and lack of sleep sense. Sleep disorders are diagnosed as symptoms that last for three months and occur at least three or more times a week (American Psychiatric Association, 2013). Sleep disorders are also a core symptom of many mental illnesses, such as depression, anxiety, and cognitive dysfunction. They can be a cause or a manifestation of mental illness (Alvaro et al., 2017).

Nightmares are common among adolescents, which typically occur

Abbreviations: GAD-7, Generalized Anxiety Disorder Scale; ICSD-3, International Classification of Sleep Disorders, third edition; ISI, Insomnia Severity Index; NDQ-CV, Nightmare Distress Questionnaire; PDQ-D, Perceived Deficits Questionnaire-Depression; PHQ-9, Patient Health Questionnaire.

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during REM sleep. According to statistics, 7 % of adolescents aged 12–18 years from China have had nightmares in the previous month (Chiu et al., 2012). The International Classification of Sleep Disorders, third edition (ICSD-3) defines nightmares as "coherent dream sequences that seem real and become increasingly more disturbing as they unfold. Emotions usually involve anxiety, fear or terror. The dream content most often focuses on imminent physical danger to the individual, but may also involve other distressing themes" (Mainieri et al., 2021). Evidence shows that nightmares are related to many negative health conditions, such as insomnia, drowsiness, emotional and behavioral disorders, post-traumatic stress disorder, and suicidal concept (Liu et al., 2019; Zhou et al., 2020; Liu et al., 2017; Karia et al., 2016; Russell et al., 2018). Nightmares affect daytime functioning, decrease overall well-being, increase anxiety and stress before and after sleep, and correspond to negative emotions (Schredl et al., 2021; Antunes-Alves and De Koninck, 2012; Carr et al., 2021).

Cognitive function includes six domains: language, sensorimotor function, executive function, learning and memory, complex attention, and social cognition. Cognitive abilities are key to optimizing academic success, interpersonal connections, and interactions among adolescents. However, nightmares may lead to impaired cognitive function, learning efficiency, and learning quality (Donnelly et al., 2016). According to a meta-analysis based on a large sample (N = 1533) (Hadie et al., 2021), episodic memory and working memory are two important cognitive abilities that facilitate learning and problem solving, and they are particularly sensitive to acute sleep loss (Lim and Dinges, 2010). Further, sleep has been found to help consolidate night time memories (Jano et al., 2021), and school performance in children and adolescents is strongly associated with nightmares, followed by sleep quality and duration. The temporo-parietal junction (TPJ) and medial Prefrontal cortex (mPFC) play a critical role in the cognitive cortex in wakefulness. Specifically, the TPJ contributes to the theory of mind, empathy, and social cognition in wakefulness. The mPFC is associated with awareness, introspection, attention, and emotion recognition. These two brain regions are also involved in sleep regulation, particularly REM sleep (D'Atri et al., 2019). Solms's research suggests that specific brain damage during nightmares can affect certain cognitive functions (Solms, 2000).

Most previous studies have focused on insomnia in adults with only a few studies on the adolescent population, specifically regarding situations of nightmares, insomnia, depression, anxiety, and cognitive defects. Moreover, previous studies have shown that nightmares can cause insomnia, depression, anxiety, and cognitive deficits; however, the relationship between the three variables caused by nightmares has not been clarified. Therefore, this study hypothesizes that nightmares directly predict cognitive deficits and that insomnia, depression, and anxiety play a chain mediating role between nightmares and cognitive deficits. This study analyzes the differences in nightmares, insomnia, depression, anxiety, and cognitive deficits among different characteristics of adolescent. Further, it examines the mediating effect of insomnia, depression, and anxiety on nightmares and cognitive deficits to explore the internal mechanism and influencing factors of adolescents nightmares and cognitive deficits. Thus, it provides important evidence for the prevention and intervention of different characteristics of adolescents nightmares and to maintain the physical and mental health of adolescents.

2. Methods

2.1. Participants and procedure

This study selected adolescents from Hebei and Shandong provinces as the research sample and obtained data in the form of questionnaire online survey. Before the administration of the questionnaire, the project team conducted special training for school principals. After the training, the questionnaire was provided, and participants' data were collected. The school principal was responsible for the online questionnaire survey of the students. The respondents were required to complete the answers independently in strict accordance with the instructions. The school principal supervised the answering process and completed all the questionnaires on site. Before starting the questionnaire, the research content was explained and informed consent was sought from parents, which was provided via electronic signature. After entering the mini program of the questionnaire, the respondents were expected to first read all the contents of the study again; they could enter the formal answer only after they read and agreed to the contents. This study was approved by the Ethics Committee of Beijing Huilongguan Hospital (Approval No. 2021-17-Department), and all respondents provided informed consent for participation. The study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. A total of 6397 questionnaires were collected from March 17 to May 14, 2021, of which 6014 were valid, with an effective questionnaire recovery rate of 94.01 %. Among them, 2950 were females, and 3064 were males, aged between 12 and 18, with an average age of 16.13. The exclusion criteria of invalid questionnaires were incomplete questionnaire content and shortened answer time.

2.2. Measurements

Self-compiled general information questionnaire: This included age, gender, grade (senior/junior high school), academic performance of the class (poor/medium/excellent), residence (city/rural), and other general information.

Nightmare Distress Questionnaire (NDQ-CV): Nightmares were assessed using the Chinese version of the NDQ-CV. There are 14 items in total. Each item has a score of 1 (never) to 5 (always). The 14 items' scores were added to produce a total nightmare distress score, which ranged from 14 to 70. The higher the score, the more serious is the level of nightmare distress. The internal consistency of the scale is good, and the Cronbach's alpha coefficient is 0.88 (Liu et al., 2021; Böckermann et al., 2014).

Insomnia Severity Index (ISI): Insomnia symptoms were assessed using the ISI. There are 7 items in total. Each item has a score of 0 (none) – 4 (extremely severe), grade 5, with a total score of 0–28. The higher the score, the more serious is the insomnia. Among them, 0–7 points are insomnia of no clinical significance, 8–14 points are considered mild insomnia, 15–21 points are considered moderate insomnia, and 22–28 points are considered severe insomnia. In this study, a score < 7 means no insomnia, and a score ≥ 7 means insomnia. The internal consistency of the scale is good, and the Cronbach's alpha coefficient is 0.74 (Bastien et al., 2001; Savard et al., 2005).

Patient Health Questionnaire (PHQ-9): Depression symptoms were assessed using the PHQ-9 (Spitzer et al., 1999; Kroenke et al., 2001; Wittkampf et al., 2007; Levis et al., 2019). There are 9 items in total. Each item has a score of 0 (not at all)–3 (almost every day), with a total score of 0–27. The higher the score, the more serious is the depression. Among them, 0–4 points indicate no obvious depressive symptoms, 5–9 points are for mild depression, 10–14 points indicate moderate depression, 15–19 points are for severe depression, and $\geq$20 points denote extremely severe depression. In this study, a score <5 means no depression, and a score >5 means depression. The internal consistency of the scale is good, and the Cronbach's alpha coefficient is 0.85 (Wang et al., 2014; Zhang et al., 2013).

Generalized Anxiety Disorder Scale (GAD-7): Anxiety symptoms were assessed using the Chinese version of the GAD-7 (Spitzer et al., 2006; Xu et al., 2018; He et al., 2010). There are 7 items in total. Each item has a score of 0 (not at all)–3 (almost every day), with a total score of 0–21. The higher the score, the more serious is the anxiety. Among them, 0–4 points are for no anxiety symptoms, 5–9 points indicate mild anxiety, 10–14 points are for moderate anxiety, and

15–21 points indicate severe anxiety. In this study, a score <5 means no anxiety, and a score >5 indicates the presence of anxiety. The internal consistency of the scale is good, and the Cronbach's alpha coefficient is 0.92 (Beck et al., 1997).

Perceived Deficits Questionnaire-Depression (PDQ-D): Cognitive deficits symptoms were assessed using the PDQ-D, which comprises 20 items, including planning/attention, retrospective memory, and prospective memory. Each item was scored on a scale of 0 (never) to 4 (always), with a total score of 0–80. Factors 4, 5, 8, 9, 12, 13, and 20 were added together to give the score of planning/attention. Factors 1, 2, 3, 6, 10, 11, 17, 18, and 19 add up to the score for retrospective memory, and factors 7, 14, 15, and 16 add up to the score for prospective memory. The higher the score, the higher is the cognitive impairment. The internal consistency of the scale is good, and the Cronbach's alpha coefficient is 0.81–0.96 (Shi et al., 2017).

2.3. Statistical analyses

We used SPSS 22.0 for data analysis. Non-normal distribution of measurement data was represented by median (inter-quartile spacing) [M (p25, p75)], and comparison between groups was tested by the Mann-Whitney U and Kruskal-Wallis test. Spearman correlation analysis and the SPSS function "PROCESS macro" were used for correlation and mediation analyses, respectively. The significance of the mediating effect was tested by the bootstrap method. When the sample size is 5000, and the 95 % confidence interval does not include 0, it indicates that there is a mediating effect. The difference was statistically significant ($p < 0.05$).

3. Results

3.1. Statistical differences

Table 1 shows the nightmare, insomnia, depression, anxiety, and cognitive deficits scores in different characteristics of adolescents. There were statistically significant differences in nightmare scores among adolescents of different genders, grades, and academic performance. Among them, female adolescents (Z = 10.514, $p < 0.05$), senior high school (Z = 3.108, $p < 0.05$), and poor academic performance (Z = 32.526, $p < 0.05$) had higher nightmare scores. There was no statistical significance in the differences in nightmare scores among adolescents living in different places ($p > 0.05$). There were statistically significant differences in insomnia scores among adolescents with different genders, grades, and academic performance. Among these, female adolescents (Z = 5.431, $p < 0.05$), senior high school (Z = 12.533, $p < 0.05$), and poor academic performance (Z = 51.841, $p < 0.05$) had higher insomnia scores. There was no statistical significance in the differences in insomnia scores among adolescents living in different places ($p > 0.05$). Further, there were statistically significant differences in depression scores among adolescents of different genders, grades, academic performance, and places of residence. Among these, females (Z = 8.835, $p < 0.05$), senior high school (Z = 12.337, $p < 0.05$), poor academic performance (Z = 191.337, $p < 0.05$), and living in cities (Z = -2.482, $p < 0.05$) had higher depression scores. Moreover, there were statistically significant differences in anxiety scores among adolescents of different genders, grades, academic performance, and residence. Among these, female adolescents (Z = 10.295, $p < 0.05$), senior high school (Z = 10.876, $p < 0.05$), poor academic performance (Z = 76.446, $p < 0.05$), and living in cities (Z = -3.124, $p < 0.05$) had higher anxiety scores. Additionally, there were statistically significant differences in cognitive deficit scores among adolescents of different genders, grades, and academic performance. Among these, female adolescents (Z = 11.448, $p < 0.05$), senior high school (Z = 8.433, $p < 0.05$), and poor academic performance (Z = 91.481, $p < 0.05$) had higher cognitive deficit scores. There was no statistical significance in the differences in cognitive deficit scores among adolescents living in different places ($p >$

Table 1
Nightmare, insomnia, depression, anxiety, and cognitive deficits scores in different characteristics of adolescents.

Variables	Sex				Grade				Academic record				Region			
	Male n = 2950	Female n = 3064	z	p	Junior high school	Senior high school	z	p	Poor	Medium	Excellent	z	p	City	Rural	z	p
	M (P25, P75)	M (P25, P75)			M (P25, P75)	M (P25, P75)			M (P25, P75)	M (P25, P75)	M (P25, P75)			M (P25, P75)	M (P25, P75)		
Nightmare	14 (14, 19)	16 (14, 22)	10.514	0.000	15 (14, 20)	15 (14, 21)	3.108	0.002	16 (14, 23)	15 (14, 20)	15 (14, 20)	32.526	0.000	15 (14, 2)	15 (14, 20)	−0.812	0.417
Insomnia	1 (0, 6)	2 (0, 6)	5.431	0.000	1 (0, 4)	3 (0, 6)	12.533	0.000	3 (0, 7)	2 (0, 6)	2 (0, 5)	51.841	0.000	2 (0, 6)	2 (0, 6)	0.057	0.945
Depression	3 (0, 7)	4 (1, 8)	8.835	0.000	2 (0, 6)	4 (1, 8)	12.337	0.000	6 (2, 9)	3 (0, 7)	3 (0, 6)	191.337	0.000	4 (0, 8)	3 (0, 7)	−2.482	0.013
Anxiety	1 (0, 4)	2 (0, 6)	10.295	0.000	0 (0, 4)	2 (0, 6)	10.876	0.000	2 (0, 7)	1 (0, 5)	1 (0, 4)	76.446	0.000	1 (0, 6)	1 (0, 5)	−3.124	0.002
Cognitive dysfunction	4 (0, 19)	10 (1, 23)	11.488	0.000	4 (0, 19)	9 (1, 22)	8.433	0.000	14 (1, 27)	6 (0, 20)	5 (0, 18)	91.481	0.000	8 (0, 21)	7 (0, 20)	−1.354	0.176
Planning/ concentration	1 (0, 7)	4 (0, 9)	10.582	0.000	1 (0, 7)	4 (0, 9)	10.690	0.000	5 (0, 11)	2 (0, 8)	2 (0, 7)	101.462	0.000	3 (0, 8)	2 (0, 8)	−1.725	0.085
Retrospective memory	2 (0, 9)	5 (0, 11)	11.773	0.000	2 (0, 9)	4 (0, 10)	6.269	0.000	6 (0, 12)	3 (0, 10)	3 (0, 9)	80.126	0.000	4 (0, 10)	3 (0, 10)	−0.866	0.386
Prospective memory	0 (0, 3)	1 (0, 3)	7.628	0.000	0 (0, 3)	0 (0, 3)	5.357	0.000	1 (0, 4)	0 (0, 3)	0 (0, 2)	93.082	0.000	0 (0, 3)	0 (0, 3)	−2.606	0.009

M (P25, P75): median (inter-quartile spacing).

0.05).

3.2. Correlation analysis

Table 2 shows the correlation analysis between nightmares, insomnia, anxiety, depression, and cognitive deficits. Correlation analysis showed that cognitive deficits were significantly positively correlated with nightmares (r = 0.629, $p < 0.01$), insomnia (r = 0.645, $p < 0.01$), depression (r = 0.677, $p < 0.01$), and anxiety (r = 0.655, $p < 0.01$). Nightmares were positively correlated with insomnia (r = 0.553, $p < 0.01$), depression (r = 0.534, $p < 0.01$), and anxiety (r = 0.539, $p < 0.01$). Insomnia was positively correlated with depression (r = 0.686, $p < 0.01$) and anxiety (r = 0.652, $p < 0.01$). Notably, all variables were significantly correlated, which was suitable for further testing the mediation effect.

3.3. Mediation model

Table 3 shows the chain mediating effects of insomnia, depression, and anxiety on the relationship between nightmares and cognitive deficits. Nightmares were chosen as the independent variable, cognitive deficits as the dependent variable, and insomnia and depression as intermediate variables. The results show that the model fits well as shown in Fig. 1. Nightmares directly affect cognitive deficits, with a direct effect of 0.7008 and an effect size of 49.22 %. Nightmares indirectly affect cognitive deficits through insomnia, which, in turn, plays a mediating role between nightmares and cognitive deficits, with a mediating effect value of 0.247 and effect size of 17.35 %. Further, nightmares indirectly affect cognitive deficits through depression, which, in turn, plays a mediating role between nightmares and cognitive deficits, with a mediating effect value of 0.2061 and effect size of 14.48 %. Nightmares indirectly affect cognitive deficits by affecting insomnia and then depression symptoms; together, they play a chain mediating role between nightmares and cognitive deficits, with a mediating effect value of 0.2698 and effect size of 18.94 %. The indirect effect was the sum of the mediation effects of the three mediation paths—0.7229; the effect quantity was 50.77 %, and the total effect was 1.4238.

Path analysis was also conducted for the same set of variables. The results show that the model fits well as shown in Fig. 2. Nightmares directly affect cognitive deficits, and the direct effect is 0.7057 with an effect size of 49.56 %. Nightmares indirectly affect cognitive deficits through insomnia, which, in turn, plays a mediating role between nightmares and cognitive deficits, with a mediating effect value of 0.3152 and effect size of 22.14 %. Further, nightmares indirectly affect cognitive deficits through anxiety, which plays a mediating role between nightmares and cognitive deficits, with a mediating effect value of 0.2012 and effect size of 14.13 %. Nightmares indirectly affect cognitive deficits by affecting insomnia and then anxiety symptoms; together, they play a chain mediating role between nightmares and cognitive deficits, with a mediating effect value of 0.2016 and effect size of 14.16 %. The indirect effect was the sum of the mediation effects of the three mediation paths—0.7181; the effect quantity was 50.44 %, and the total effect was 1.4238.

Table 3
Chain mediating effects of insomnia, depression, and anxiety on the relationship between nightmares and cognitive deficits.

Path	Effect	Effect size, %	*p*	SE	95 % CI
Nightmare-Insomnia-Cognitive deficits	0.3592 * 0.6878 = 0.2470	17.35 %	<0.001	0.0213	0.2062, 0.2902
Nightmare-Depression-Cognitive deficits	0.1656 * 1.2446 = 0.2061	14.48 %	<0.001	0.0162	0.1754, 0.2388
Nightmare-Insomnia-Depression-Cognitive deficits	0.3592 * 0.6035 * 1.2446 = 0.2698	18.94 %	<0.001	0.0149	0.2417, 0.2999
Indirect effect	0.7229	50.77 %	<0.001	0.0253	0.6749, 0.7725
Direct effect	0.7008	49.22 %	<0.001	0.0228	0.6562, 0.7455
Total effect	1.4238		<0.001	0.0219	1.3808, 1.4668
Nightmare-Insomnia-Cognitive deficits	0.3592 * 0.8777 = 0.3152	22.14 %	<0.001	0.012	0.2743, 0.3584
Nightmare-Anxiety-Cognitive deficits	0.1575 * 1.2775 = 0.2012	14.13 %	<0.001	0.0169	0.1693, 0.2364
Nightmare-Insomnia-Anxiety-Cognitive deficits	0.3592 * 0.4393 * 1.2775 = 0.2016	14.16 %	<0.001	0.0142	0.1751, 0.2310
Indirect effect	0.7181	50.44 %	<0.001	0.0257	0.6693, 0.7703
Direct effect	0.7057	49.56 %	<0.001	0.0235	0.6596, 0.7518
Total effect	1.4238		<0.001	0.0219	1.3808, 1.4668

CI: confidence interval; effect size, %; the ratio of indirect effect to total effect; SE: standard error.

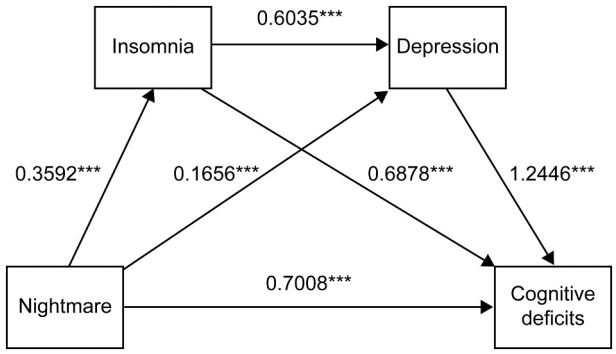

Fig. 1. The chain mediation model for insomnia, depression, nightmares, and cognitive deficits. ***$p < 0.001$.

Table 2
Correlation analysis between nightmares, insomnia, anxiety, depression, and cognitive deficits.

	1	2	3	4	5	6	7	8
Nightmare	1.000							
Insomnia	0.553**	1.000						
Depression	0.534**	0.686**	1.000					
Anxiety	0.539**	0.652**	0.794**	1.000				
Cognitive deficits	0.629**	0.645**	0.677**	0.655**	1.000			
Planning/concentration	0.600**	0.633**	0.671**	0.661**	0.954**	1.000		
Retrospective memory	0.616**	0.622**	0.646**	0.620**	0.975**	0.888**	1.000	
Prospective memory	0.572**	0.572**	0.608**	0.585**	0.869**	0.826**	0.827**	1.000

** $p < 0.01$.

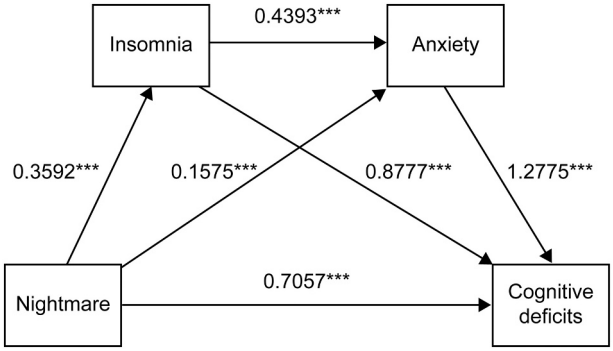

Fig. 2. The chain mediation model for insomnia, anxiety, nightmares, and cognitive deficits. ***$p < 0.001$.

4. Discussion

This is one of the first studies to explore the situation of nightmares, insomnia, depression, anxiety, and cognitive deficits among adolescents with different characteristics. The study found that adolescents who were in high school and had low academic performance were more likely to have nightmares. Further, females who were in high school and had low academic performance were more likely to suffer from insomnia, depression, and anxiety and had higher cognitive deficits scores. High school is a time of considerable stress for students, and 27 % of adolescents reported experiencing high levels of stress, with school being their biggest source of stress (83 %) (Casement et al., 2016). Students are required to keep up with school assignments (such as tests, homework, etc.), balance social life, sports, and extracurricular activities, and deal with parental and social expectations. During high-school years, several external factors can lead to shorter sleep times by lengthening bed times. These factors include participation in extracurricular activities, excessive homework, evening use of electronic devices, and earlier wake-up timing. School start-time is a major limiting factor for wake-up time and is a key factor in sleep deprivation and circadian sleep disruption in adolescents (Lo et al., 2016). Zulfiqar et al. (2022) found that in adolescents, academic performance was the number one factor affecting adolescent sleep, and insomnia was directly related to poor academic performance. Many studies have reported a link between poor sleep and poor academic performance. School stress increases with age, with girls experiencing more stress than boys (El-Sheikh et al., 2020). Some sex-specific social and biological changes occur during adolescence, such as girls experiencing higher stress levels and stronger responses to stress owing to differences in sex hormone changes associated with neuroendocrine increased sensitivity (Murray et al., 2019). Moreover, sex hormones affect mood, and girls' emotions are more easily affected by the change (Salk et al., 2017) and may increase the risk of depression and anxiety. This suggests that we should take positive measures for susceptible groups, such as providing convenient channels for help and timely psychological counseling to minimize the risk of insomnia.

Furthermore, this study showed that there were significant correlations among the variables of cognitive deficits, nightmares, insomnia, depression, and anxiety. This is consistent with past research showing that patients with frequent nightmares are more likely to complain of insomnia than those with other sleep disorders. Insomnia increases negative emotions, decreases positive emotions, and alters the way adolescents understand, express, and regulate emotions (Palmer and Alfano, 2017). For example, in a previous study, it was found that as little as five nights of sleep shortening (6.5 h per night) caused healthy adolescents (12–18 years old) to experience a deterioration in mood and a decrease in their ability to regulate emotions (Stenson et al., 2021). Insomnia can also cause impairment in cognitive areas such as attention, memory, executive ability, emotional control, language fluency (Huang et al., 2021), and psychomotor speed. The lesser the quality of sleep, the greater the area and extent of cognitive deficits (Guo et al., 2017).

Finally, this study constructed a chain mediation model to explore the relationship between insomnia, depression, and anxiety in adolescents and their nightmares and cognitive deficits. This study shows that nightmares have a direct and indirect effect on cognitive deficits, which indicates that nightmares are a key factor affecting cognition in adolescents. This is consistent with previous research results—the cognitive function of adolescents with long-term nightmares will decline, and daytime attention and memory will be significantly affected (Zheng et al., 2020).

The structural equation model analysis of this study shows that nightmares can affect college students' cognitive performance by influencing their insomnia symptoms. In a similar study that examined the effects of sleep duration on emotional functioning and cognitive performance in 32 adolescents (12–18 years of age), Vriend et al. (2013) found that compared with adolescents who were sleep-restricted for 1 h, those who slept four nights longer performed better on measures of emotional regulation, working memory, and attention. Further, they can also affect adolescents' cognitive performance by increasing their negative emotions (depression and anxiety). Compared with adolescents who had good sleep, those who had frequent nightmares showed changes in their emotional responses, and those who had frequent nightmares had twice the risk of depression compared to those who did not have nightmares (Baglioni et al., 2011; Querstret et al., 2020). Bad experiences with nightmares can make adolescents anxious and even depressed. This leads to cognitive deficits in daytime attention, memory, and intelligence. Additionally, Tomaso et al. (Tomaso et al., 2021) found that adolescents with frequent nightmares (ages 12–18) showed significantly fewer positive emotions than adults with frequent nightmares (ages 30–60), suggesting that adolescents may be particularly prone to mood disorders after nightmares. Studies have shown that some electrophysiological features associated with REM sleep play a key role in emotional regulation. Brain regions involved in emotion regulation during wakefulness, such as the limbic system and the reward-dopaminergic system, are also activated during REM sleep, which is associated with nightmares (Scarpelli et al., 2019).

Moreover, insomnia, depression, and anxiety play a chain mediating role between nightmares and cognitive deficits in adolescents. The more serious the nightmares are, the greater the impact on insomnia, which leads to higher negative emotions (depression and anxiety) and increasing degree of cognitive deficits. Studies have found that nightmares in early adolescence may alter the cortex-brain circuitry through the disruptive effects of over-arousal and sleep deprivation (Clement-Carbonell et al., 2021), thus affecting volitional activity, emotional regulation, and cognitive function (Chen et al., 2020). Executive function is the higher level of cognitive function, the behavioral direction we use to achieve all our goals, and is made up of seemingly unrelated but interrelated functions, such as inhibition, working memory, and set-shifting. The prefrontal cortex controls executive function and is also responsible for sleep regulation. Thus, nightmares affect efficiency and function in the prefrontal cortex, and nightmares affect executive functioning (Karr et al., 2018). Good sleep is an important sign of the physical and mental health of adolescents. After being affected by nightmares, adolescents' sleep patterns will be broken, which will lead to various sleep problems (Sampasa-Kanyinga et al., 2018; Shearston et al., 2021). Sleep problems can lead to daytime fatigue. Persistent and recurrent symptoms of fatigue severely interfere with the social life of the patient, resulting in self-care deficits, loss of learning ability, and a serious impact on the outcome of the disease. Severe physical illness and psychological distress can lead to more emotional problems and cognitive deficits, which often affect processing speed or the ability to pay attention or make decisions. Therefore, insomnia, depression, and anxiety in adolescents play a chain mediating role between nightmares and cognitive deficits. It is important to raise awareness of nightmares in adolescents, detect and treat them early, minimize negative harm, and

limit the prevalence of chronic nightmares as much as possible. Further, it is significant to maintain the physical and mental health development of adolescents.

4.1. Limitations

This study used large sample data to explore the internal influencing mechanism of adolescents' insomnia and cognitive deficits for the first time. Although it has obvious advantages, it also has certain limitations. First, as this is a cross-sectional study, it is impossible to know the dynamic relationship between variables. In the future, longitudinal studies and behavioral experiments with insomnia and cognitive deficits in adolescents should be improved to further investigate the causal relationship between variables. Second, all variables in this study were measured in the form of subjective reports, which may lead to reporting bias. More objective methods can be used for measurement in the future. Third, the data source of this study is single, which may lead to volunteer bias. In the future, similar studies with a larger sample size that involves individuals from across the nation can be explored.

5. Conclusion

Studies of numerous Chinese adolescents have shown that nightmares are associated with cognitive deficits in adolescents. Furthermore, the link between nightmares and cognitive deficits was mediated mainly by insomnia, depression, and anxiety. These findings suggest that clinicians should identify adolescents with frequent nightmares early and provide timely treatment to minimize negative outcomes and possibly limit the chronicity of nightmare disorder. To reduce the risk of insomnia, depression, anxiety, and cognitive deficits, it is considerably important to maintain the physical and mental health development of adolescents.

CRediT authorship contribution statement

Li-Gang Zhang: Conceptualization, Methodology, Validation, Data curation, Writing - original draft, Funding acquisition.
Ling-Fei Cheng: Conceptualization, Methodology, Data curation.
Ting-Ting Wang, Lei-Lei Wang, Shuang-Jiang Zhou, and Yan-Hong Luo: Investigation, Methodology, Data curation.
Jing-Xu Chen: Conceptualization, Project administration, Supervision, Writing – review and editing.

Li-Gang Zhang and Ling-Fei Cheng contributed equally to this work and should be regarded as joint first authors.

All authors have approved the submitted manuscript.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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