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Chain mediating effect of fatigue, anxiety symptoms on the relationship between perceived stress and insomnia in Chinese researchers

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Abstract

Background At present, insomnia, fatigue and mental health problems of researchers are increasingly prominent, and they are facing great perceived stress. However, there are relatively few studies on Chinese researchers, and the relationship between them is not clear. This study mainly explores the current status of insomnia and fatigue symptoms of Chinese researchers, and the relationship with perceived stress and anxiety symptoms.

Methods A Total of 961 Chinese researchers participated in this nationwide cross-sectional survey. The Pittsburgh Sleep Quality Index (PSQI), Fatigue Severity Scale (FSS), Perceived Stress Scale (PSS) and Generalized Anxiety Disorder Scale (GAD-7) were used for evaluation. The count data were analyzed by chi-square analysis, the measurement data were analyzed by independent sample t test, and the chain mediation analysis was used to explore the relationship between insomnia, fatigue symptoms, perceived stress and anxiety symptoms.

Results The prevalence of insomnia symptoms was 36.9% and The prevalence of fatigue symptoms was 68.7% among Chinese researchers. The multivariate covariance analysis showed that the scores of anxiety symptoms, perceived stress, and fatigue symptoms of the researchers with insomnia symptoms were higher than those of the researchers without insomnia symptoms ($p<0.001$). Insomnia and fatigue symptoms were related to lifestyle and exercise. Fatigue and anxiety symptoms played a chain mediating role between perceived stress and insomnia symptoms (Total indirect effect: 0.180(0.146,0.211), Direct effect: 0.036(-.0.001,0.079), Total effect: 0.216(0.190,0.242)).

Conclusion Insomnia and fatigue symptoms are serious among Chinese researchers. We should pay attention to the sleep and mental health problems of researchers, strengthen psychological intervention, and reduce their perceived stress level.

Keywords Research personnel, Insomnia symptoms, Fatigue symptoms, Perceived stress level, Chain mediation effect

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Introduction

Researchers are those engaged in scientific research, experimentation and development, including professionals in the fields of natural science research, social science research and medical research [1]. researchers usually work in scientific research institutions, universities or enterprises. For some researchers working in universities and hospitals, their workload is heavy, not only undertaking research work, but also often undertaking teaching, medical work. In recent years, with the emphasis on scientific research and development, the proportion of investment in science and technology has increased, and the assessment of scientific researchers has become more stringent. Scientific researchers are facing huge psychological pressure, and their mental health problems such as insomnia, anxiety, fatigue symptoms have become more prominent [2, 3].

Research conducted on college students and staff members indicates That insomnia symptoms have significantly increased in Recent years. The incidence of insomnia among college students has risen from 24% To 40%, while among staff members, it has increased from 15% To 42% [4]. The Research results for doctoral students show that 59% of them have deterioration in sleep quality [5]. Study conducted on Chinese Researchers aged between 25 and 55 revealed That approximately 38.66% of the participants exhibited insomnia symptom, which aggravated physical diseases such as hypertension [6]. Another study involving 14,552 scientific researchers from Chinese research institutions, medical and health care institutions, enterprises and public institutions, as well as universities, found That 48.6% of the participants suffered from insomnia symptoms. For those whose sleep Duration was less Than 5 h per day, The overall prevalence of cardiovascular diseases among scientific Researchers was 40.3% [7].

Perceiving stress refers to the psychological experience of an individual regarding the demands, challenges or threats in the environment, as well as their ability to cope with them. Studies have shown that researchers are under significant psychological pressure, especially during the pandemic [8, 9]. Application for funding projects, high impact factor journals, academic competition and other multiple pressures, but for Chinese researchers, due to the constraints of various factors, the pressure is more prominent, for example, for research university teachers, in the scientific research work at the same time, as well as engaged in teaching work, but also face the "either up or go" pressure [10]. A survey of researchers in Beijing showed That 69.7% of researchers felt work pressure in The past 1 month, and in the mental stress test, blood pressure and heart rate were significantly higher than that at rest,, and the cardiac sympathetic parasympathetic nerve was in an unbalanced state [6]. It has been confirmed in different populations that there is a significant positive correlation between perceived stress and insomnia symptoms [11–14]. Excessive stress leads to excessive arousal in cognition and emotions, which in turn causes insomnia [15].

Fatigue presents as persistent weariness impacting both cognitive and physical functioning, with symptoms resistant to conventional restorative measures. Researchers fatigue symptoms are also worthy of attention, most researchers are in a state of physical and mental exhaustion, according to the "Fourth National Survey Report on the Status of Science and Technology Workers", The average weekly working hours of science and technology workers Reached 49.7 h, which is 24.3% more than the legal working hours. researchers often refer to their working hours as "711," which refers To working 11 h a day, seven days a week [16]. In a global survey involving over 13,000 Researchers, 38% of the respondents indicated that they often felt overly stressed at work in the past month. Persistent fatigue also interacted with insomnia symptoms, resulting in a decline in the researchers' sleep quality [17]. Moreover, studies had shown that perceptual pressure affects an individual's fatigue symptoms, increasing both psychological and physiological fatigue [18, 19].

Long-term fatigue and work pressure also seriously affect the mental health of staff. In the "2019 Survey Report on the Mental Health Status of scientific and Technological Workers", a survey of more Than 10,000 scientific and Technological workers in Research institutes of the Chinese Academy of Sciences and their affiliated organs and enterprises found that more than 50% of scientific and Technological personnel have different degrees of anxiety. Of these, 42.2% had mild anxiety, 8.8% had moderate anxiety, and 4.5% had severe anxiety [20]. Another survey of graduate students from 234 Research institutions in 26 countries found That graduate students Reported 6 times more anxiety and depression symptoms than the general population [21]. A study conducted on public universities revealed That the incidence of anxiety symptoms among staff members was as high as 60% [22]. The occurrence of anxiety symptoms is related to many factors. Previous studies have found that mental fatigue and perceived stress are both associated with anxiety, and weaken the ability of emotional regulation [23–25]. Anxiety symptoms are risk factors for insomnia. Individuals with anxiety symptoms are in a highly alert, fearful and tense state of heightened arousal, which exacerbates insomnia symptoms [26, 27]. Studies have shown That 60% To 70% of patients with generalized anxiety disorder exhibit prolonged sleep latency and reduced deep sleep [28].

Although the relationship between perceived stress and insomnia symptoms has been extensively studied,

the specific mechanisms of the chain mediating effects of fatigue and anxiety have not been fully explored within the Chinese research population. Furthermore, as mentioned above, it can be observed that the perceived stress is a significant factor contributing to fatigue, anxiety, and insomnia symptoms, and there is a close correlation among these symptoms. However, the specific causal relationship between them merits further exploration. Therefore, this study initially aimed to examine whether fatigue symptoms and anxiety symptoms independently play a mediation role between perceive stress and insomnia symptoms, and whether there is a chain mediation effect. Based on the literature review and considering the complex interrelationships among these variables, we proposed two hypotheses: Hypothesis 1: Fatigue symptoms and anxiety symptoms Respectively play a mediation role between perceived stress and insomnia symptoms. Hypothesis 2: Fatigue symptoms and anxiety symptoms play a chain mediation effect role between perceived stress and insomnia symptoms, that is, perceived stress leads to the aggravation of fatigue symptoms, which in turn causes anxiety symptoms, and ultimately leads to insomnia symptoms.

Materials and methods

Design and participants

We conducted an anonymous cross-sectional survey of Chinese researchers using snowball sampling. We though the Wenjuanxing platform (https://www.wjx.cn/app/survey.aspx) To assess the insomnia and fatigue sympto ms and Related influencing factors from August 26 To October 1, 2022. We referred To the prevalence Rate of insomnia disorder in the general population in the meta-analysis, which was 30.30%. Using G*Power 3.1.9.7 for sample size calculation of a single group rate, we determined That the total sample size should be 36. However, 961 graduate students and Researchers from research institutions, universities, hospitals and other institutions from 31 provinces across The country participated in the survey, each subject can only complete one Response, the questionnaire is mainly sent through wechat and QQ, excluding 24 invalid participants, a Total of 937 participants from 30 provinces (Supplementary Material Fig. 1) completed The assessment. The effective Response rate was 97.5%. The selection criteria of participants were: (1) junior and senior school students; (2) Able to read and understand Chinese questionnaires; (3) Wechat users or QQ users; (4) Voluntary participation in the investigation; (5) Submit only one survey using the same IP. The exclusion criteria are as follows: (1) Participants who did not complete their answers; (2) Participants who answer questions too quickly (less Than 5 min).

This study was approved by the Medical Ethics Committee of Beijing Huilongguan Hospital (Approval No. 2021–18-Department). Before the investigation, informed consent was obtained from each participant and an electronic informed consent was signed.

Assessment tools and procedure

Sociodemographic factors

Demographic data, including gender, age, occupation and education level, were collected by self-made scale.

Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used To evaluate the sleep quality of the Researchers in the past 1 month. The scale mainly includes seven factors: subjective sleep quality, sleep latency, sleep persistence, sleep efficiency, sleep disturbances, use of hypnotic drugs and daytime dysfunction. Each entry is 0–3 points, and The total score is 0–21 points. PSQI ≥ 8 points was considered as poor sleep quality [29, 30]. In this study, the PSQI demonstrated good reliability, with a Cronbach's α coefficient of 0.710, and This scale also has good structural validity, with a KMO value of 0.735.

Fatigue Severity Scale

The fatigue severity scale (FSS) was used To evaluate the fatigue symptoms of Researchers. The scale had 9 items, each item was composed of "strongly disagree" to "strongly agree", and The score was 0–7. The score < 4 was no fatigue, 4.0-4.9 was moderate fatigue, and ≥ 5 was severe fatigue. The results show that FSS has good reliability, validity and internal consistency [31]. The FSS exhibited excellent reliability in this study, with a Cronbach's α of 0.928, and This scale also has good structural validity, with a KMO value of 0.927.

Anxiety Symptom

Researchers' anxiety levels were assessed using the Generalized Anxiety Disorder Scale-7 (GAD-7) developed by Spitzer et al., which consisted of 7 items and mainly assesses anxiety symptoms in The last 2 weeks. Each item was scored 0–3 on a scale of 0–21 overall, with higher scores indicating more severe anxiety symptoms. The total score of 0–4 was no anxiety symptom; 5–9 was mild anxiety; 10–14 was classified as moderate anxiety; ≥15 was classified as severe anxiety [32]. The GAD-7 exhibited excellent reliability in this study, with a Cronbach's α of 0.947, and This scale also has good structural validity, with a KMO value of 0.934.

Perceived Stress

The Perceived Stress Scale (PSS) was used to evaluate the stress perception of adolescents. PSS is one of the most commonly used research tools for measuring individual perceived or perceived stress levels at home and abroad. The tool not only measures the level of stress

an individual is currently experiencing, but also assesses whether the external pressure exceeds the individual's ability to cope, mainly looking at the degree of stress an individual has experienced in daily Life in the last month Due To unpredictable, uncontrollable or overburdened stress. In this study, a 10-item short-form scale (PSS-10) was used, and Licket 0–4 rating scale was adopted, with a Total score of 0–40, the higher the score, the more severe the perceived stress [33]. The results show that the Chinese version of PSS-10 has good reliability and validity in our study, with a Cronbach's α coefficient of 0.782, and with a KMO value of 0.886.

Statistical analysis

All data in This study were statistically analyzed using SPSS 26.0 software. The Harman single-factor test method was used to examine whether there was a common method bias. Taking age, gender, whether engaging in swing sports and resistance exercise as covariates, a multivariate covariance analysis was used to compare the differences in perceived stress levels, anxiety symptoms, and fatigue symptoms between researchers with insomnia and those without. Using partial correlation analysis, the correlations among perceived stress, fatigue, anxiety symptoms, and insomnia symptoms were explored. The level of significance was set at $p < 0.05$.

We used Model 6 of SPSS 26.0 PROCESS v 3.4 to analyze the chain mediation effect to explore the role of fatigue symptoms, and anxiety symptoms in perceived stress and insomnia [34]. Perceived pressure was as The independent variable, insomnia symptoms as the dependent variable; fatigue symptoms and anxiety symptoms as the mediating variables; age, gender, whether engaging in swing sports and Resistance exercise as covariates. The output indicators included total effect, direct effect and indirect effect. We used the bootstrap method to test the mediating effect, set the sample size as 5000, and chose a 95% confidence interval (CI) for direct and indirect effects. A 95%CI for indirect effects that does not contain a zero value is statistically significant.

Results

Common method bias test

The results of The Harman single-factor test showed that the cumulative variance explained by the first common factor was 19.64%, which was less Than the standard critical value of 40%. Therefore, there was no serious common method bias in this study.

The distribution of each dimension factor of PSQI scale and socio-demographic characteristics for insomnia and fatigue symptoms

A Total of 937 researchers who met The Research criteria were included in the analysis, including 414 males (44.2%) and 523 females (55.8%), with an average age of 31.96 ± 8.95 years old. A Total of 346 (36.9%) Researchers had insomnia symptoms, and 644 (68.7%) researchers had fatigue symptoms. The average sleep Duration of The Researchers was 6.75 ± 1.05 h. 387 (41.3%) of The Researchers went to bed between 23 and 24 am, and 140 (14.9%) of The Researchers went to bed longer than 24 am. The total PSQI score of the researchers was (6.88 ± 3.77). The scores of each dimension in descending order are: daytime dysfunction was (1.63 ± 0.97), subjective sleep quality was (1.21 ± 0.73), sleep latency was (1.20 ± 0.98), sleep disturbance was (1.04 ± 0.61), sleep duration was (0.88 ± 0.62), sleep efficiency was (0.43 ± 0.74), hypnotic drugs were (0.15 ± 0.53) (Fig. 1). Education level has an impact on insomnia symptoms, the incidence of bachelor's degree is the highest, followed by doctoral degree, master's degree and post-doctoral degree are lower ($p = 0.002$). Researchers working in research institutes have the most severe insomnia and fatigue symptoms ($p = 0.044$ and $p = 0.040$). Compared with researchers in other provinces, the incidence of insomnia symptoms among researchers in Beijing is higher ($p = 0.009$). Age and gender had no effect on the researchers' symptoms of insomnia and fatigue. (Table 1).

Effects of lifestyle and exercise on insomnia and fatigue symptoms

Researchers with a napping habit had higher incidence of insomnia and fatigue symptoms ($p = 0.006$ and $p = 0.041$). Researchers who engaged in weekly aerobic exercise had a lower incidence of fatigue symptoms ($p = 0.004$). The incidence of insomnia symptoms was lower in the researchers who performed weekly swing exercises ($p = 0.013$ and $p = 0.009$) and resistance exercises ($p = 0.042$ and $p = 0.039$). Researchers who exercised for more Than 30 min had a lower incidence of insomnia symptoms ($p<0.001$). Moderate-intensity exercise researchers had a lower incidence of insomnia symptoms($p = 0.001$). Researchers who had physical diseases and played mobile phones for more Than 30 min during sleep had a higher incidence of insomnia symptoms ($p<0.001$ and $p = 0.012$). (Table 2).

Differences scores in the perceived stress, fatigue and anxiety in the group with or without insomnia symptoms

Multivariate analysis of covariance showed that the perceived stress total score, subjects' stress perception and the ability to cope with stress score of researchers with insomnia symptoms was higher than those without insomnia symptoms ($p<0.001$). Researchers with insomnia symptoms had higher symptoms of fatigue, and anxiety symptoms than those without insomnia symptoms ($p<0.001$) (Fig. 2).

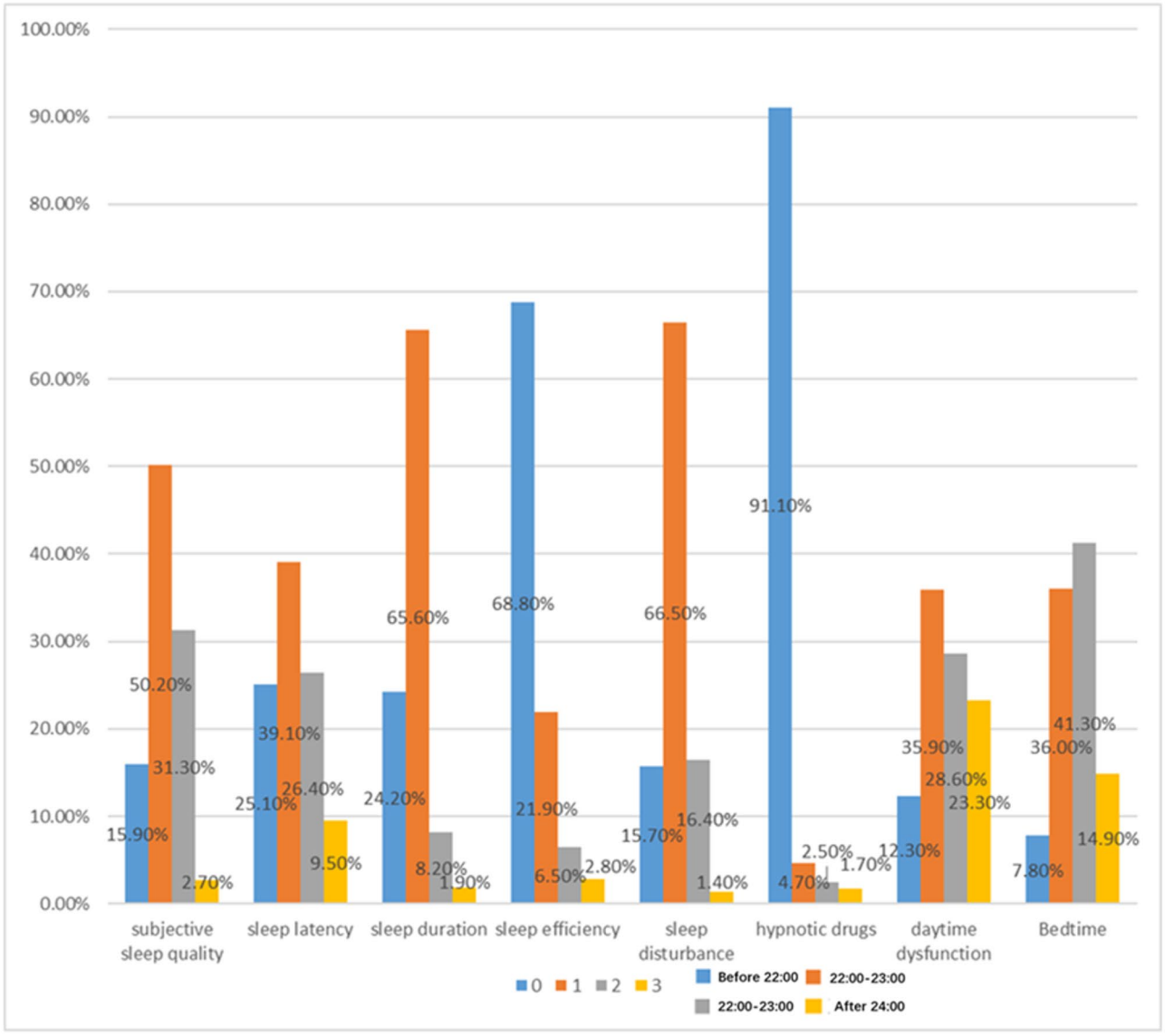

Fig. 1 Each dimension of researchers on PSQI scale (*N* = 937)

Relationship between insomnia symptoms and perceived stress, fatigue and anxiety symptoms

Partial correlation analysis showed that the PSQI total and each factor score were positively correlated with subjects' stress perception, perceived stress total score, fatigue symptoms and anxiety. Subjective sleep quality, sleep latency, anxiety symptoms were negatively correlated with the ability to cope with stress score. There was a pairwise correlation between fatigue and anxiety symptoms (all $p<0.05$) (Fig. 3).

Mediation analysis

The chain mediation effect showed That model fit well. Total effect of perceived stress on insomnia symptoms was 0.216, with direct effect was 0.036. However, The 95% confidence interval (CI) of The direct effect includes 0, indicating a complete mediation effect. And The 95% CI of all indirect effects do not include 0, which indicates That all indirect effects are effective, with the total indirect effect being 0.180, accounting for 83.33% of The total effect. Path 1, path 2, and path 3 are Respectively 0.037 (17.13%), 0.129 (59.72%), and 0.014 (6.48%) (Tables 3 and 4; Fig. 4).

Discussion

This study provides an important Theoretical contribution to Chinese Researchers by clarifying the chain mediation effect role of fatigue and anxiety symptoms between perceived stress and insomnia symptoms. Our research results are consistent with the 3P factors model of insomnia and the susceptibility-stress model, further confirming the role of long-term stress as an inducing

Table 1 Socio-demographic characteristics and association with insomnia and fatigue symptoms ($N=937$)

variables	*n*	%	Insomnia symptoms			fatigue symptoms		
			n	%	*P*	*n*	%	*P*
Gender					0.138			0.055
Male	414	44.2	142	34.3		271	65.6	
Female	523	55.8	204	39.0		373	71.3	
Educational level					0.002			0.515
Bachelor's degree	133	14.2	59	44.4abc		95	71.4	
Master's degree	443	47.3	145	32.7c		298	67.3	
Doctorate degree	261	27.9	114	43.7b		177	67.8	
Postdoctoral	100	10.6	28	28.0ac		74	74.0	
Vocational institutions					0.044			0.040
Colleges	453	48.3	147	32.5		296	65.3	
Hospitals	112	12.0	44	39.3		73	65.2	
Research institutes	231	24.7	99	42.9[a]		174	75.3[a]	
Others	141	15.0	56	39.7		101	71.6	
Age (years old)					0.952			0.166
< 35	595	63.5	221	37.1		417	70.1	
35–45	260	27.7	96	36.9		178	68.5	
> 45	82	8.8	29	35.4		49	59.8	
Beijing					0.009			0.140
Yes	446	47.6	184	41.3		317	71.1	
No	491	52.4	162	33.0		327	66.6	

and persistent factor leading to sleep disorders. Notably, by demonstrating how stress manifests through both fatigue and anxiety symptoms, we have expanded these models and exerted a compound influence on insomnia. This mechanistic insight offers a detailed understanding of the association between occupational stress and sleep disorders, which has not been fully explored in previous studies targeting academic populations.

Our study found that Chinese researchers have a higher incidence of insomnia symptoms (36.9%) and fatigue symptoms (68.7%). 75.8% researchers self-reported less Than 7 h of sleep, The phenomenon of staying up late is common among Chinese Researchers, and 14.9% last went To bed after 12 am, which may be related to the fact that scientific researchers have to undertake other affairs such as teaching, meetings, laboratory and clinical work during the daytime working time. Insufficient sleep duration, staying up late, excessive labor, etc., also make the daytime function disorders of researchers, easy to be sleepy and insufficient energy during the day, aggravate the fatigue symptoms. In addition, the fatigue symptoms were also related to low satisfaction, job burnout, physical health problems and other factors [35–40]. Nature reader survey showed That about 40% scientific researchers work more Than 60 h a week, and another study showed The weekly working hours of college teachers Reach 51.64 h, The proportion of severe overwork is 50.81% [41]. Our research has revealed That Chinese Researchers suffer from more severe insomnia symptoms. A study conducted on PhDs found that the incidence of anxiety and insomnia was only 20% in European [42]. This might be attributed to the fact that Chinese researchers are under greater professional pressure and have more demanding tasks [43].

Our research has found that Lifestyle and exercise have an impact on insomnia and fatigue symptoms. Previous studies on The adult population have shown that using mobile phone for more than 30 min before bedtime can lead to shorter sleep duration and excessive daytime sleepiness. This is because the blue light emitted by electronic screens inhibits the secretion of melatonin and affects the sleep rhythm [44]. Regarding exercise, the incidence of insomnia and fatigue symptoms among Chinese researchers participating in the swing sports was lower. Swing sports can mobilize all muscle systems, making people more focused and keeping the brain active, which helps to delay brain aging and protect the cardiovascular system, and reduce all-cause mortality [45]. Aerobic exercise and resistance exercise can reduce the incidence of fatigue symptoms, which is consistent with studies from abroad [46, 47]. A randomized controlled trial showed that moderate aerobic exercise has a recovery effect on mental fatigue, which may be related to the increase in cerebral blood flow and tissue oxygenation levels after exercise, thereby promoting the oxygenation of the prefrontal lobe and increasing the content of neurotrophic factors and other nutrients in the circulation [48, 49].

In terms of demographic factors, our study found that undergraduate and doctoral students had a higher incidence of insomnia than master's and post-doctoral

Table 2 Effects of lifestyle and exercise on insomnia and fatigue symptoms (*N* = 937)

variables	*n*	%	Insomnia symptoms			fatigue symptoms		
			n	%	*P*	*n*	%	*P*
Napping					0.099			0.655
No	255	27.2	105	41.2		255	69.8	
Yes	682	72.8	241	35.3		682	68.3	
Snoring					0.006			0.041
No	507	54.1	167	32.9		334	65.9	
Yes	430	45.9	179	41.6		310	72.1	
Smoking					0.755			0.749
No	866	92.4	321	37.1		594	68.6	
Yes	71	7.6	25	35.2		50	70.4	
Drinking					0.240			0.613
No	687	73.7	246	35.8		469	68.3	
Yes	250	26.3	100	40.0		175	70.0	
Aerobic exercise					0.143			0.004
No	180	19.2	75	41.7		140	77.8	
Yes	757	80.2	271	35.8		504	66.6	
Swing sports					0.013			0.009
No	748	79.8	291	38.9		529	70.7	
Yes	189	20.2	55	29.1		115	60.8	
Resistance exercise					0.042			0.039
No	852	90.9	306	35.9		594	69.7	
Yes	85	9.1	40	47.1		50	58.8	
Relaxing exercise					0.877			0.795
No	854	91.1	316	37.0		588	68.9	
Yes	83	8.9	30	36.1		56	67.5	
Exercise duration					0.064			<0.001
≤ 30 min	370	39.5	150	40.5		284	76.8	
> 30 min	567	60.5	196	34.6		360	63.5	
Exercise intensity					0.001			0.846
Mild	149	15.9	58	38.9		105	70.5	
Moderate	490	52.3	154	31.4		337	68.8	
Severe	298	31.8	134	45.0		202	67.8	
Somatic disease					<0.001			0.466
No	235	25.1	111	47.2		166	70.6	
Yes	702	74.9	235	33.5		478	68.1	
Play mobile phone before bed					0.012			0.786
≤ 30 min	108	11.5	28	25.9		73	67.6	
> 30 min	829	88.5	318	38.4		571	68.9	

students in Terms of education level, which is generally consistent with previous findings. Previous studies have found that the incidence of insomnia symptoms among college students is 31.4%, which is higher than that of the general population [50, 51]. The reason for the increase may be related to the impact of COVID-19. During theCOVID-19, students often suspend classes, take online classes at home or in dormitories, have circadian rhythm disorders, and many students have psychological problems such as anxiety and depression, which also aggravate insomnia symptoms [52–55]. Many doctoral students are faced with the pressure of scientific research, timely graduation, job hunting and employment, and the COVID-19 epidemic has caused many doctoral students to fail to complete research experiments on time, and the incidence of delayed graduation has increased, which will lead to insomnia [56–59]. Researchers in scientific research institutes have a higher incidence of insomnia and fatigue symptoms, which may be related to the high pressure of scientific research institutes and more heavy scientific research tasks they undertake [60, 61].

Our research shows that stress is closely related to insomnia symptoms, and researchers with insomnia symptoms have increased subjective perceived stress levels and decreased stress coping ability. Previous studies have shown a Link between stress and insomnia, both The 3P factor model of insomnia and the diathesis induced model emphasize the influence of perceived

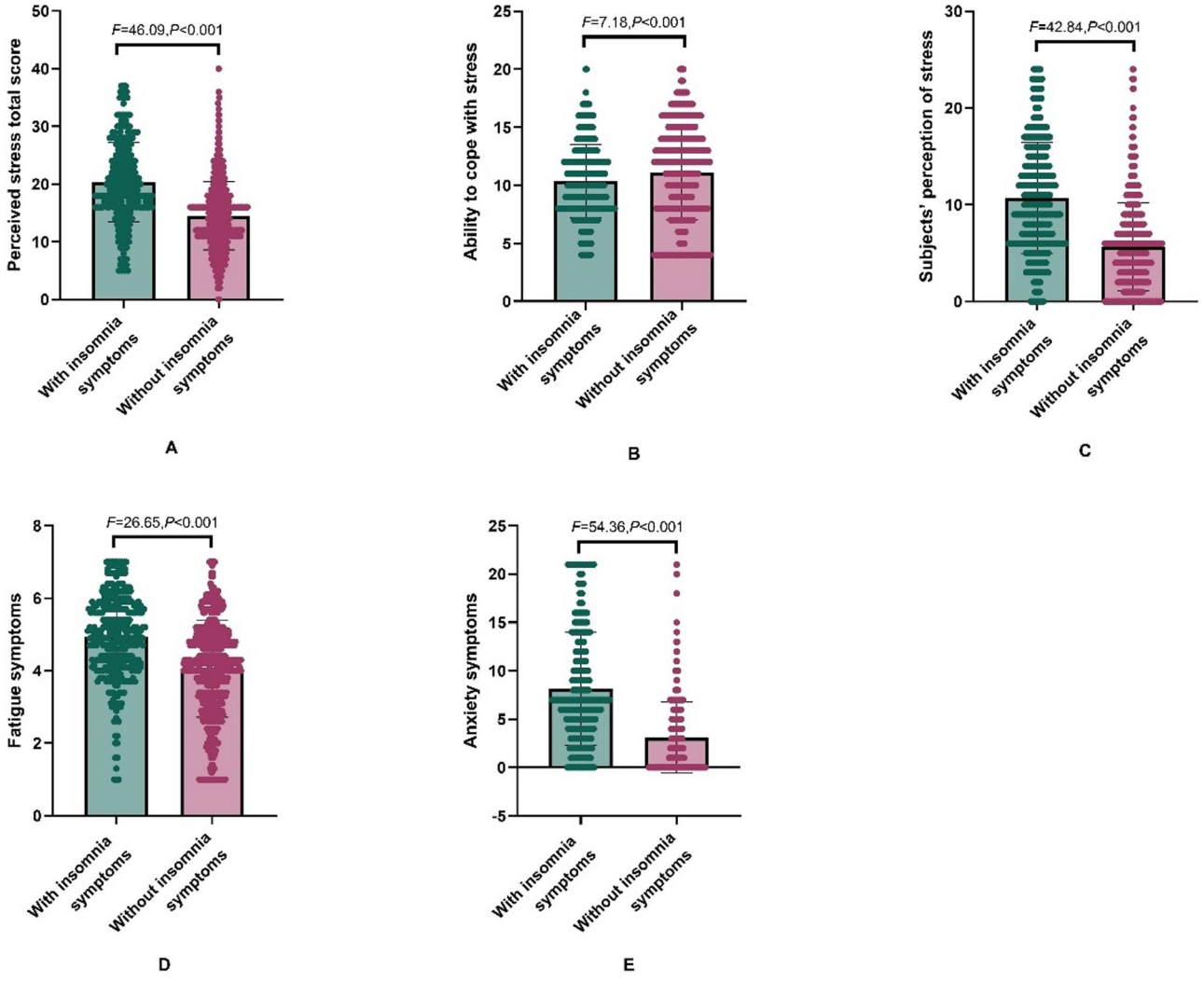

Fig. 2 Differences in perceived stress, anxiety symptoms, and fatigue symptoms between Chinses researchers with and without insomnia symptoms (N = 937). Note: **A** indicates that perceived stress total score among Chinese researchers with insomnia symptoms was higher than those without; **B** indicates that ability to cope with stress score among Chinese researchers with insomnia symptoms was lower than those without; **C** indicates that subjects' perception of srtess score among Chinese researchers with insomnia symptoms was higher than those without; **D** indicates that fatigue symptom score among Chinese researchers with insomnia symptoms was higher than those without; **E** indicates that anxiety symptom score among Chinese researchers with insomnia symptoms was higher than those without

stress on insomnia [13, 62]. When an individual is in a state of stress for a long time, it will produce negative coping ways such as over-preparation, helplessness and rejection, and will produce negative emotions and emotional dysregulation such as anxiety, tension and irritability, which will make the individual in a state of high awareness and lead to insomnia [63]. Studies have shown that people with chronic stress have increased insomnia symptoms such as difficulty initiating sleep, frequent nocturnal awakening, early morning awakening [15]. Our study also found that researchers with insomnia symptoms had higher anxiety and fatigue symptoms, which is consistent with the results of previous studies. Studies have shown that fatigue will cause individual production, physical and psychological fatigue, resulting in technical stress, loss of motivation, insomnia, daytime sleepiness, sleep rhythm disorders and other sleep disorders[64–66].

In the influence of stress on insomnia symptoms, the changes in the hypothalamic-pituitary-adrenal (HPA) axis caused by stress cannot be ignored. When individuals are in a state of chronic stress, the HPA axis remains continuously activated, causing the hypothalamus to release corticotropin-releasing hormone (CRH), which in turn stimulates the pituitary gland to secrete adrenocorticotropic hormone (ACTH), ultimately leading to excessive secretion of cortisol by the adrenal cortex. Under normal physiological conditions, cortisol levels exhibit diurnal rhythmic changes, being higher in the morning

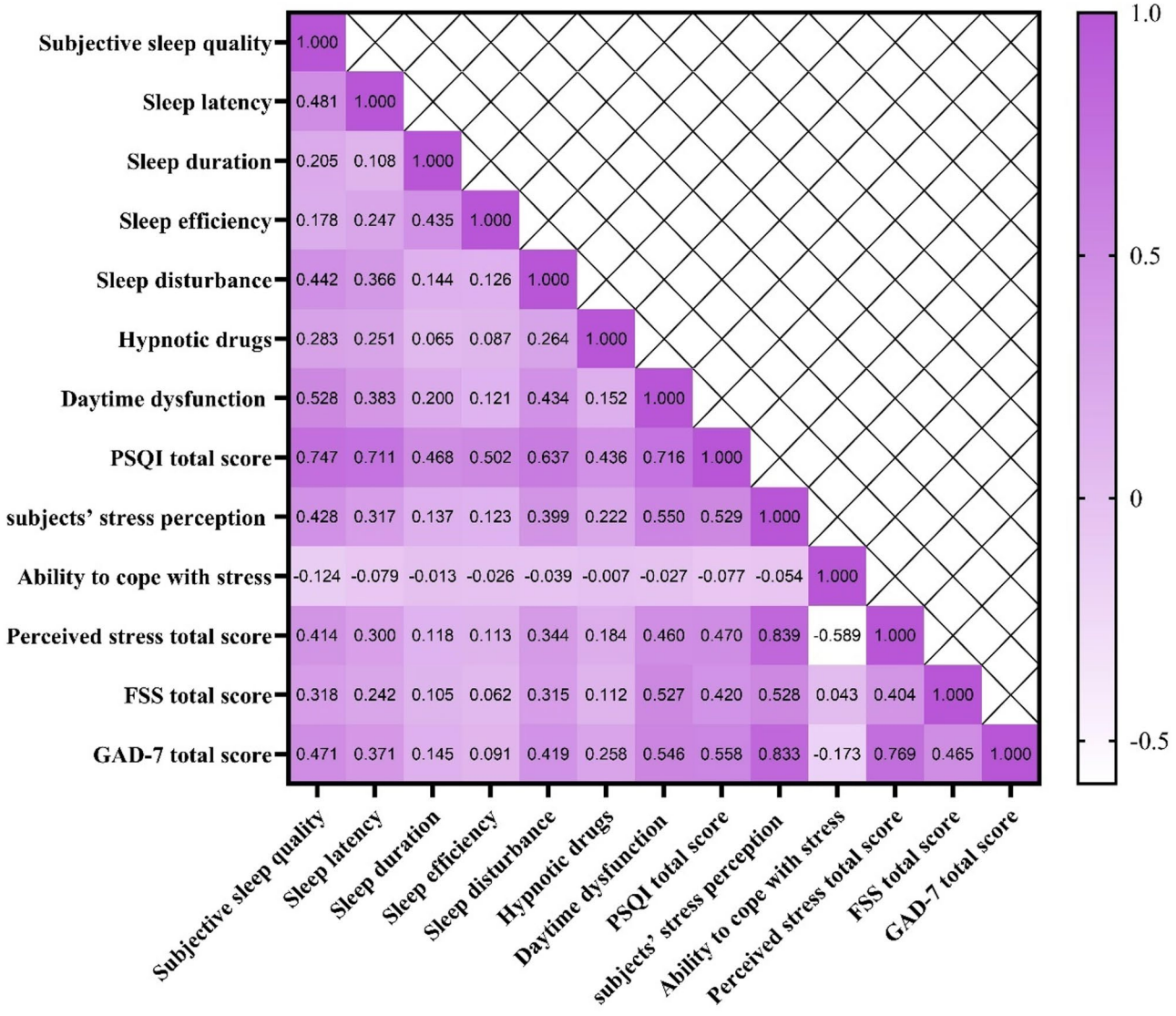

Fig. 3 Relationship between insomnia symptoms and perceived stress, fatigue and anxiety symptoms ($N=937$)

Table 3 The role of fatigue and anxiety symptoms in the chain mediation of perceived stress and insomnia symptoms ($N=937$)

Mediation model	Mediation path	effect (β)	SE	The proportion of mediation effect (%)[a]	95%CI	
					lower	upper
Indirect effect	Path 1: X→M1→Y	0.037	0.007	17.13	0.025	0.051
	Path 2: X→M2→Y	0.129	0.016	59.72	0.098	0.159
	Path 3: X→M1→M2→Y	0.014	0.003	6.48	0.009	0.019
	Total indirect effect	0.180	0.016	83.33	0.146	0.211
Direct effect		0.036	0.019	16.67	−0.001	0.079
Total effect		0.216	0.013		0.190	0.242

Path1: X→M1→Y: Perceived stress total score → Fatigue symptoms → PSQI total score

Path2: X→M2→Y: Perceived stress total score → anxiety symptoms → PSQI total score

Path3: X→M1→M2→Y: Perceived stress total score → Fatigue symptoms → anxiety symptoms → PSQI total score

X Perceived stress total score, *M1* Fatigue symptoms, *M2* Anxiety symptoms, *Y* PSQI total score

[a]The percentage representing the total effect

Table 4 Model fitting index of the chain mediation effect of fatigue symptoms and anxiety symptoms in the perceived stress and insomnia symptoms ($N=937$)

Regression equation		Model fitting index				Standardized regression coefficient		
Dependent variable	**Independent variable**	***R***	R^2	**F**	***p***	**β**	**t**	***p***
Fatigue symptoms	Perceived stress total score	0.421	0.177	40.143	<0.001	0.707	13.47	<0.001
Anxiety symptoms	Perceived stress total score	0.789	0.623	255.841	<0.001	0.526	31.439	<0.001
	Fatigue symptoms					0.080	8.372	<0.001
PSQI total score	Perceived stress total score	0.594	0.352	72.190	<0.001	0.036	1.896	0.058
	Fatigue symptoms					0.053	6.645	<0.001
	Anxiety symptoms					0.245	9.381	<0.001

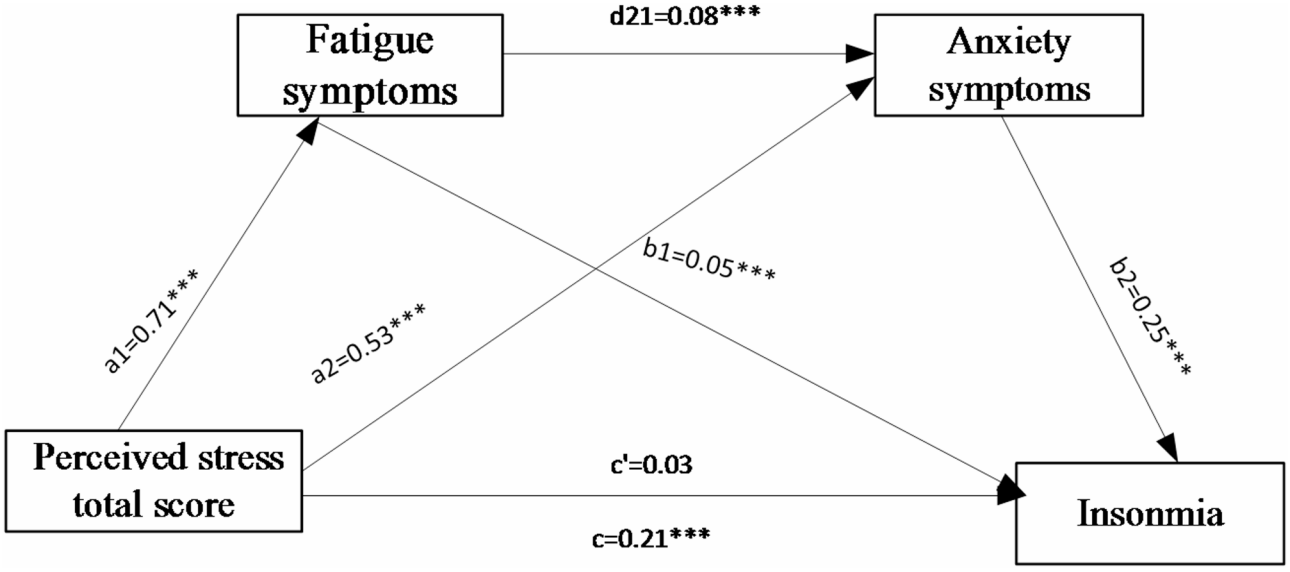

Fig. 4 The role of fatigue and anxiety symptoms in the chain mediation of perceived stress and insomnia symptoms ($N=937$). Note: a1 represents the effect value of perceived stress total score positively predicting figure symptom; a2 represents the effect value by which perceived stress total score positively predict anxiety symptoms; b1 represents the positive predictive effect value of fatigue symptoms on anxiety symptoms; b2 represents the effect value of the positive prediction of anxiety symptoms on insomnia; c′ represent direct effect; c represents the total effect; d21 represents the effect value of fatigue symptoms positively predicting anxiety symptoms ***: $p<0.001$

and lower at night; however, chronic stress disrupts this rhythm, resulting in abnormal elevation of cortisol levels at night, directly inhibiting the secretion of melatonin and reducing the duration of slow-wave sleep, and prolonging the sleep latency [67]. Moreover, excessive secretion of CRH can activate the locus coeruleus-norepinephrine (LC-NE) system, enhancing the reactivity of the amygdala, while inhibiting the function of the prefrontal cortex (PFC), leading to decreased cognitive control ability and increased rumination thinking, further exacerbating the difficulty in falling asleep [68].

Our study also used the mediation effect model to explore the relationship between perceived stress, fatigue, anxiety and insomnia symptoms. The results first showed that fatigue symptoms and anxiety symptoms were mediating factors between perceived stress and fatigue symptoms respectively, and there was a chain mediation effect between them. At a higher level of perceived pressure, individual workload increases, leading to fatigue symptoms, resulting in insomnia symptoms, and perceived pressure will make the body in a state of anxiety, which will also affect insomnia[69, 70]. This also suggests that for researchers with insomnia symptoms, we should pay attention to their psychological stress levels, maintain appropriate relaxation, and reduce fatigue and anxiety symptoms.

Our research also has the following limitations. Firstly, this study adopted a cross-sectional subjective scale assessment method based on self-reporting. This assessment method lacks objective evaluation indicators and may lead to information bias, thereby limiting the inference of causal relationships. Additionally, this study employed a snowball sampling method, with a relatively small sample size, concentrated in regions such as Beijing, Guizhou, and Shandong. The assessment was conducted through electronic questionnaires, and the participants were not controlled by the researchers, which may affect the representativeness of the sample

and result in selection bias. Moreover, key demographic and professional variables such as research field, working hours, and professional title were not systematically collected, thus making it impossible to assess their confounding effects. Finally, this study focused on individual-level factors while ignoring the influence of institutional factors (such as economic pressure or working environment), which may have a significant impact on sleep and fatigue conditions.

In future studies, a multi-center design should be adopted to ensure broader representativeness in terms of regions and institutions. A mixed method combining quantitative scales, structured interviews, and objective PSG assessments should be employed to enhance the reliability of the data. Stratified sampling by factors such as research field, career title, region, workload and family support. should be conducted to identify specific subgroups of insomnia and fatigue symptoms. Longitudinal follow-up should be used to clarify causal relationships. This will enhance the general applicability and practical significance of the research results, making them applicable to different types of research groups.

Conclusion

Our research shows that the incidence of insomnia and fatigue symptoms among Chinese researchers is very high. Researchers with insomnia had higher perceived stress and more severe fatigue and anxiety symptoms. Fatigue and anxiety symptoms played a chain mediating role between perceived stress and insomnia symptoms. This indicates that the mental health problems of Chinese researchers cannot be ignored. The national science and education departments should establish a mental health support system for researchers, optimize the research management and assessment mechanisms, and improve crisis intervention and emergency support, in order to create a healthy research culture environment.

Supplementary Information

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Supplementary Material 1

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Data sharing and declaration

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

Authors' contributions

L.-L. W.: formal analysis, methodology, project administration, writing original draft; S.-J. Z.: conceptualization, data curation, investigation; H.-L. L.: data curation, investigation, project administration; M. -Q., G. -L: conceptualization, investigation, project administration, resources; J.-X. C. ang Y.-L. T.: funding acquisition, project administration, supervision, writing – review & editing.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The ethical standards from the 1964 Declaration of Helsinki and its later amendments were followed, and approval for this study was granted by the Ethics Committee of Beijing Huilongguan Hospital. All respondents and their guardians provided informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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