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The Sleep Quality of Han Chinese and Tibetan Firefighters at High Altitude: A Field Study

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Background: The sleep quality of Han Chinese and Tibetan firefighters at high altitude remains poorly understood. This study investigates the prevalence of sleep disturbances in these groups and whether ethnicity affects sleep quality in these two populations.

Methods: Male firefighters were recruited from China Fire and Rescue stations at high altitude of 500 m, 2570 m, and 4509 m in Southwest China. The Pittsburgh Sleep Quality Index (PSQI) assessed sleep quality, considering scores >5 as poor sleep quality. Symptoms of anxiety and depression were evaluated using the 7-item Generalized Anxiety Disorder Questionnaire (GAD-7) and the 9-item Patient Health Questionnaire (PHQ-9).

Results: As altitude increased, the total PSQI scores of Han Chinese firefighters showed a non-statistically significant rise: 4 (2−5) at 500 m, 4 (3−6.75) at 2570 m, and 5 (2.75−6) at 4509 m. Poor sleep quality prevalence also rose: 23%, 31%, and 44%, respectively. In contrast, the sleep quality of Tibetan firefighters remained relatively stable and was better than that of their Han Chinese counterparts. Furthermore, the GAD-7 and PHQ-9 scores were higher in Han Chinese firefighters compared to Tibetan firefighters. The PSQI score was positively correlated with GAD-7 scores ($\rho = 0.454$, $p < 0.001$) and PHQ-9 scores ($\rho = 0.380$, $p < 0.001$) but negatively correlated with Tibetan ethnicity ($\rho = –0.228$, $p < 0.001$). Logistic regression analysis indicated that, compared to Tibetans, being Han Chinese (odds ratio [OR] = 3.050, 95% confidence interval [CI]: 1.214–7.665) and having higher GAD-7 scores (OR = 1.816, 95% CI: 1.332–2.477) were independently associated factors for poor sleep quality.

Conclusion: This study suggests that Han Chinese firefighters in this field sample across these stations are at greater risk of poor sleep quality than Tibetan firefighters, with elevated GAD-7 scores being a potential contributing factor for poor sleep quality.

Keywords: anxiety, firefighter, high altitude, Han Chinese, ethnicity, sleep

Introduction

More than 140 million people live at altitudes above 2500 m. The reduced oxygen pressure in the air at these heights lowers the amount of oxygen transported to body tissues, adversely affecting the function of many organs. Sleep is essential for life, and quality rest is crucial for emotional stability and normal cognitive function.[1] Sleep disturbance can lead to daytime dysfunction and impair cognitive abilities after exposure to high altitude.[2,3] The Tibetan population is believed to be the oldest group residing at high altitudes in Southwest China and has developed greater adaptability to these conditions than the Han Chinese. This adaptation has allowed them to successfully reproduce and thrive at significant elevations.[4,5] In a study examining acute exposure to a simulated altitude of 5000 m, it was suggested that Tibetans possess mechanisms that help them maintain better sleep structure and improved tissue oxygenation during sleep compared to the Han Chinese, who are typically from lower altitudes.[6] However, research on sleep quality differences between Tibetans and Han Chinese chronic exposure to high altitudes is limited, and the risk factors for sleep disorders in these conditions are poorly understood, hindering effective prevention and treatment strategies.

Firefighters play a crucial role in combating wildfires and other disasters. Due to the physical, emotional, and psychological challenges inherent in their work, firefighters exhibit high rates of mental health disorders.[7] Studies have shown that firefighters are significantly more likely to experience depression and anxiety symptoms than the general

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population.[8] In the high-altitude cities of Southwest China, professional fire and rescue teams mainly consist of ethnic Tibetans and Han Chinese. The current state of their sleep quality and potential influencing factors, such as ethnicity, depression, and anxiety symptoms, remain unclear.

Since Tibetans have better sleep quality than Han Chinese individuals at high altitude, and sleep quality is associated with symptoms of depression and anxiety, we hypothesize that Han Chinese firefighters may have poorer sleep quality than Tibetans, and anxiety and depression symptoms may account for this discrepancy in sleep quality. Therefore, this study has two objectives: (1) to investigate the prevalence of sleep disturbances in both the Tibetan and Han Chinese firefighter groups at high altitude, and (2) to examine whether ethnicity, depression, and anxiety symptoms are associated with poor sleep quality in these two populations. The present study may bring an increment by demonstrating that Han firefighters stationed at high altitude report poorer sleep quality compared to Tibetan firefighters, and such sleep impairment may be correlated with anxiety and depression symptoms.

Materials and Methods

Study Design

This is a cross-sectional study conducted at three different altitudes: 500 m, 2570 m, and 4509 m, in Southwest China. The altitudes of these three fire stations represent, respectively, near sea level, high altitude, and very high altitude, making them highly representative and enabling effective comparison. The research took place in September and October 2025. The study design protocol is illustrated in Figure 1.

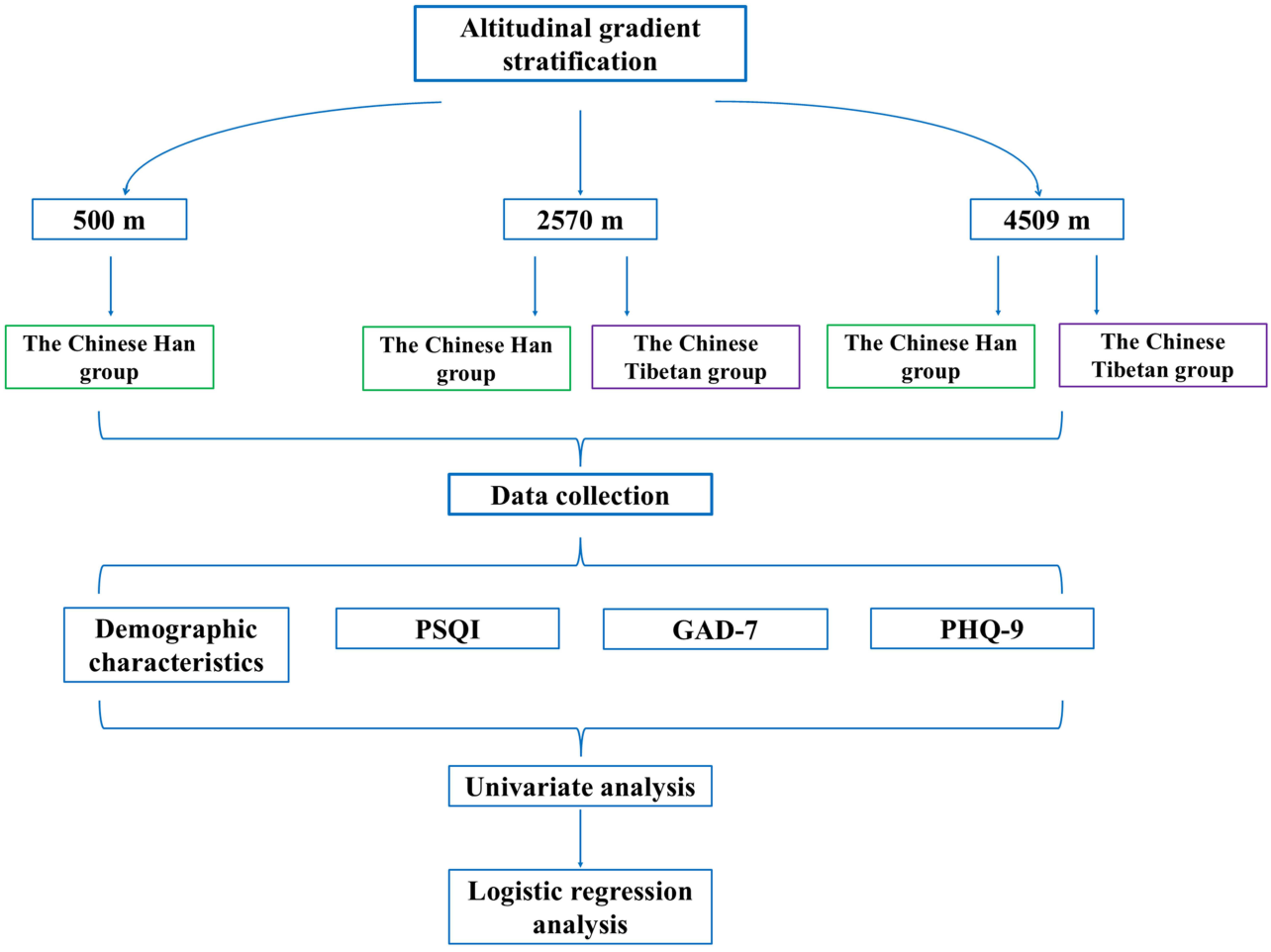

Figure 1 Study design protocol.
Abbreviations: GAD-7, the 7-item Generalized Anxiety Disorder Questionnaire; PHQ-9, the 9-item Patient Health Questionnaire; PSQI, the Pittsburgh Sleep Quality Index.

Participants

We recruited male firefighters from China Fire and Rescue stations at three different altitudes: 500 m, 2570 m, and 4509 m in Southwest China. According to the Liu et al's study,[9] they reported a prevalence of sleep disturbance among firefighters of 59.49%, assuming a 50% prevalence of poor sleep quality among Han Chinese firefighters at 4509 m altitude and 10% among Tibetan firefighters, the coefficient of determination for ethnicity relative to the other independent variables is 0.1, Han Chinese firefighters at 4509 m altitude account for 25% of the sample, with 80% power at a significance level of 0.05, the sample size calculated using PASS 11.0 is 59. The sample size of Han Chinese firefighters at 4509 m altitude is 15. In China, each county has a fire station, and our initial research subjects were all the firefighters at this fire station. Participants stationed at the 2570 m and 4509 m fire stations were further selected based on specific criteria: (1) they must have had high-altitude exposure for one month or longer, (2) they should be of Tibetan or Han Chinese descent, and (3) they must not have a history of cardiovascular or respiratory diseases. Individuals of Chinese Miao or other ethnicities, those with cardiovascular or cerebrovascular diseases, respiratory conditions, liver or kidney diseases, or malignant tumors were excluded from the study. All participants provided informed written consent and had the option to withdraw from the study at any time. The study adhered to the Declaration of Helsinki and received approval from the Ethics Committee of the General Hospital of Western Theater Command of the People's Liberation Army (Approval Identifier: 2025EC11-ky070). Demographic characteristics of the participants—including age, body mass index (BMI), ethnicity, education level, smoking and drinking habits, years of work experience, and years of high-altitude exposure—were recorded using a questionnaire.

Sleep Quality Assessment

The Pittsburgh Sleep Quality Index (PSQI) consists of 19 items organized into seven distinct components, as outlined by Buysse et al.[10] These components are: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Each component is scored on a scale of 0 to 3, and the scores are combined to yield a global PSQI score ranging from 0 to 21. A global PSQI score greater than 5 demonstrated a diagnostic sensitivity of 89.6% and specificity of 86.5% in differentiating between good and poor sleepers.[10] Originally designed to assess sleep quality in psychiatric settings, the PSQI has become a valuable tool in population-based epidemiologic research and is applicable across various demographic groups, including the Chinese Han population.[11] Additionally, the PSQI has been utilized in high-altitude research settings.[12,13] For these reasons, the PSQI was employed in the current study, and subjects with a global PSQI score greater than 5 were considered to have poor sleep quality.

Anxiety and Depression Assessment

Moving from low altitude to high altitude increases an individual's risk of experiencing depression and anxiety. To assess symptoms of anxiety and depression, the 7-item Generalized Anxiety Disorder Questionnaire (GAD-7) and the 9-item Patient Health Questionnaire (PHQ-9) were utilized.[14]

The severity of anxiety symptoms was measured using the validated Chinese version of the GAD-7, which has demonstrated satisfactory psychometric properties and is widely used across various populations.[15] The GAD-7 consists of seven items, with each item scoring from 0 ("not at all") to 3 ("nearly every day").[15] The total score for the GAD-7 ranges from 0 to 21, where a higher score indicates more severe symptoms of anxiety. The GAD-7 has been frequently used in high-altitude studies.[14,16,17] Furthermore, the GAD-7 has demonstrated good reliability and validity in Chinese populations.[15,18]

The PHQ-9 is a screening tool used to assess the presence and severity of depressive symptoms.[19,20] It evaluates the severity of depression experienced over the past two weeks through nine items. Each item is rated on a scale from 0 (not at all) to 3 (nearly every day), allowing for a total score ranging from 0 to 27 by summing the ratings across all items. Higher scores indicate greater levels of depressive symptoms. Various versions of the PHQ-9 have been developed in different languages, including Chinese.[21] Referring to previous population-based studies, the tool has demonstrated good reliability and validity, making it a simple, rapid, effective, and credible method for screening and evaluating depression

severity.[22–24] The PHQ-9 has also been utilized to measure the severity of depression among fire service recruits across China,[25,26] and in high-altitude settings.[25,27] For these reasons, the PHQ-9 was employed in the current study.

Statistical Analysis

Data are presented as mean ± standard deviation (SD), median with interquartile range, or n (%), as appropriate, and analyzed using the Statistical Package for the Social Sciences (version 22.0; IBM Corporation, Armonk, NY, USA). It is worth noting that, although the PSQI and GAD-7 scales are integer-based, the default linear interpolation method used by SPSS to calculate quartiles may result in non-integer interquartile range (IQR) values. A significance level of $p < 0.05$ was used with two-sided tests. The normality of the distribution of quantitative variables was assessed with the Kolmogorov–Smirnov test. Continuous variables were compared using either a *t*-test or a Mann–Whitney *U*-test, while categorical variables were compared with the Pearson chi-squared test. Correlations between variables were evaluated using Pearson's correlation coefficient (r) for normally distributed data or Spearman's rank correlation coefficient (ρ) for non-normal data. Factors associated with PSQI scores with p-values <0.10 in univariate analysis were included in the multivariable logistic regression analysis. In this analysis, poor sleep quality served as the dependent variable, with the independent variables including age, BMI, smoking and drinking status, ethnicity, education, years of work experience, years of high-altitude exposure, GAD-7, and PHQ-9 scores. Predictors were categorized as binary (yes/no) for factors such as smoking and ethnicity (Chinese Han or Tibetan), or as continuous variables (age, BMI, years of high-altitude exposure, GAD-7, and PHQ-9 scores). The adjusted logistic regression aimed to identify independently associated factors for poor sleep quality (see Figure 1).

Results

Participants

At an altitude of 500 m in Chengdu, the capital of Sichuan Province, we recruited 60 male firefighters from China Fire and Rescue stations, all of whom were Han Chinese. At 2570 m, Kangding, the capital of Ganzi Prefecture in Sichuan Province, we recruited 74 male firefighters. Among these, 36 were Han Chinese, while the remainder were Tibetans. At 4509 m, Nagqu, the highest-altitude prefecture-level city in China, we recruited 70 male firefighters; 18 of them were Han Chinese, and the rest were Tibetans. All firefighters reside at the fire station, where their work, training, and daily routines for rest, waking up, and meals are standardized. The demographic characteristics of the participants are presented in Table 1. As shown in Table 1, there were no significant differences in age, BMI, or smoking habits between

Table 1 The Demographic Characteristics of the Han Chinese and Tibetan Populations

Variables	500 m	2570 m		4509 m	
	Han Chinese (N=60)	Han Chinese (N=36)	Tibetan (N=38)	Han Chinese (N=18)	Tibetan (N=52)
Age (years)	27 (25–29)	25.5 (23–28.75)	26 (24–28)	25 (23–26.25)	25.5 (24–27)
BMI (kg/m^2)	22.48 (21.23–24.39)	22.58 (21.88–25.11)	22.48 (21.76–24.84)	23.13 (21.95–25.31)	22.82 (21.12–24.44)
Smoking (yes)	34 (57%)	20 (56%)	25 (66%)	9 (50%)	33 (63%)
Drinking (yes)	12 (20%)	3 (8%)	2 (5%)	0	1 (2%)
Education					
Junior school	0	0	0	0	1 (2%)
High school	17 (28%)	4 (11%)	5 (13%)	8 (44%)	10 (19%)
College	43 (72%)	32 (89%)*	33 (87%)	10 (56%)$^{\$\S}$	41 (79%)
Work tenure					
<1 year	54 (90%)	11 (31%)**	11 (29%)**	7 (39%)**	19 (37%)**
1–3 years	5 (8%)	9 (25%)	8 (21%)	8 (44%)	16 (31%)
4–6 years	1 (2%)	6 (16%)	14 (37%)	1 (6%)	12 (23%)
>6 years	0	10 (28%)	5 (13%)	2 (11%)	5 (9%)
High-altitude exposure duration (years)	0	3.46 (0.69–9.64)	3.54 (0.44–5.29)	1.08 (0.08–2.87)	2.17 (1.08–6.58)†

Notes: Values are presented as median with interquartile range or a number (%). As compared to the value of 500 m, *$p < 0.05$, **$p < 0.01$. Compared with the Han Chinese group at the same altitude, $^{\dagger}p < 0.05$. Compared with the Han Chinese population of 2570 m, $^{\$}p < 0.05$. Compared with the Tibetan population of 2570 m, $^{\S}p < 0.05$.

Table 2 The PSQI, GAD-7, and PHQ-9 Scores of the Han Chinese and Tibetan Populations

Variables	500 m	2570 m		4509 m	
	Han Chinese (N=60)	Han Chinese (N=36)	Tibetan (N=38)	Han Chinese (N=18)	Tibetan (N=52)
PSQI	4 (2–5)	4 (3–6.75)	4 (2–5)	5 (2.75–6)	3 (2–4)‡
Poor sleep quality	14 (23%)	11 (31%)	5 (13%)	8 (44%)§	6 (12%)$^{‡\$}$
GAD-7	0 (0–0)	0 (0–1.75)	0 (0–0)†	0.5 (0–2.25)*§§	0 (0–1)
PHQ-9	0 (0–2)	1 (0–3)	0 (0–2)	2 (0–4)	0 (0–2)†

Notes: Values are presented as median with interquartile range or a number (%). As compared to the value of 500 m, $^{*}p < 0.05$. Compared with the Han Chinese group at the same altitude, $^{†}p < 0.05$, $^{‡}p < 0.01$. Compared with the Han Chinese population of 2570 m, $^{\$}p < 0.05$. Compared with the Tibetan population of 2570 m, $^{§}p < 0.05$, $^{§§}p < 0.01$.
Abbreviations: GAD-7, the 7-item Generalized Anxiety Disorder Questionnaire; PHQ-9, the 9-item Patient Health Questionnaire; PSQI, Pittsburgh Sleep Quality Index.

the Han Chinese and Tibetan groups. Alcohol consumption rates were low across all groups. Additionally, the distribution of education, years of work experience, and duration of high-altitude exposure across the groups is detailed in Table 1.

Sleep Quality

As illustrated in Table 2, the global PSQI score exhibited an increasing trend among the Han Chinese groups at elevations of 500 m, 2570 m, and 4509 m. Similarly, the prevalence of poor sleep quality followed this trend. Notably, the total PSQI score for the Han Chinese population was consistently higher than that of the Tibetan population, with a statistically significant difference observed at an elevation of 4509 m above sea level. The seven component scores of the PSQI of the subjects were shown in the Supplementary Table 1. The prevalence of poor sleep quality showed comparable results across both groups (see Table 2).

Anxiety and Depression

In the Han Chinese population at an altitude of 500 m, GAD-7 scores were very low. However, as the altitude increased, GAD-7 scores also rose among the Han Chinese group. At 4509 m, the GAD-7 scores showed a significant increase compared to the scores at 500 m, reaching statistical significance. At 2570 m, the GAD-7 scores for the Han Chinese population were significantly higher than those of the Tibetan population. Additionally, the GAD-7 scores of the Han Chinese at 4509 m were considerably higher than those of the Tibetan population at 2570 m; the difference did not reach statistical significance when comparing the Han Chinese population at 4509 m to the Tibetan population at 4509 m (see Table 2).

Similarly, the PHQ-9 scores were also very low among the Han Chinese population at 500 m. As altitude increased, the PHQ-9 scores rose within the Han Chinese group. The PHQ-9 scores for the Tibetan population showed minimal change. At 4509 m, the PHQ-9 scores for the Han Chinese population were significantly higher than those for the Tibetan population (see Table 2).

Correlational Analysis

Next, we conducted a correlation analysis to identify which parameters were associated with the PSQI score. After excluding the 500 m Han Chinese firefighter sample, our results showed that the PSQI score was positively correlated with GAD-7 scores ($\rho = 0.454$, $p < 0.001$) and PHQ-9 scores ($\rho = 0.380$, $p < 0.001$), while negatively correlated with Tibetan ethnicity ($\rho = -0.288$, $p < 0.001$). Correlation analysis suggested a positive trend between PSQI scores and altitude ($p = 0.072$).

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Table 3 Risk Factors for Poor Sleep Quality Among Participants at High Altitude (N=144)

Variable	Univariable OR (95% CI)	p-value	Multivariable OR (95% CI)	p-value
Age	1.119 (0.985–1.271)	0.084		
BMI	1.173 (0.985–1.397)	0.074		
Ethnicity (Han Chinese)	3.899 (1.679–9.053)	0.002	3.050 (1.214–7.665)	0.018
Smoking	0.692 (0.308–1.558)	0.374		
Drinking	4.231 (0.992–18.042)	0.051		
Education	0.648 (0.265–1.581)	0.340		
Altitude	0.906 (0.405–2.029)	0.811		
Work tenure	1.244 (0.856–1.808)	0.253		
High-altitude exposure duration	1.000 (0.938–1.066)	0.998		
GAD-7	1.898 (1.406–2.562)	< 0.001	1.816 (1.332–2.477)	< 0.001
PHQ-9	1.102 (0.826–1.213)	0.201		

Notes: The dependent variable is poor sleep quality. Smoking, education, altitude, work tenure, high-altitude exposure duration, and PHQ-9 were not included in the multivariate logistic regression analysis because their p-values were greater than 0.1.

Abbreviations: BMI, body mass index; CI, confidence interval; GAD-7, the 7-item Generalized Anxiety Disorder questionnaire; PHQ-9, the 9-item Patient Health Questionnaire.

Logistic Regression Analyses

Finally, after excluding the 500 m Han Chinese firefighter sample, we conducted a logistic regression analysis to identify the potential contributing factors for poor sleep quality. In the univariable logistic regression analysis that included high-altitude participants, we found that being Han Chinese and having higher GAD-7 and PHQ-9 scores were significantly associated with an increased risk of poor sleep quality (see Table 3). In contrast, factors such as age, BMI, smoking and drinking status, education level, work tenure, and duration of high-altitude exposure were not associated with poor sleep quality (refer to Table 3). Following the adjusted logistic regression analysis, as referenced to the Tibetan, being Han Chinese and having higher GAD-7 scores were confirmed as independently associated factors for poor sleep quality (see Table 3).

Discussion

The primary finding of this study indicates that Han Chinese firefighters stationed at high altitude face a 3.0-fold higher risk of poor sleep quality compared to their Tibetan counterparts. Additionally, elevated GAD-7 scores (anxiety symptoms) were strongly associated with poor sleep quality, and may be a marker for identifying higher-risk individuals among high-altitude firefighters. This represents the first investigation to focus specifically on firefighters—a population at increased risk of poor sleep quality—an area that has been underexplored in western high-altitude regions of China.

In the high-altitude regions of western China, firefighters are a vital social profession due to frequent forest fires and other disasters, such as earthquakes. Newly recruited firefighters posted to high-altitude areas are required to complete six months of professional training on the plain beforehand. In their first month at the highlands, they mainly undergo altitude acclimatisation while getting familiar with local high-altitude firefighting and rescue missions. Every dormitory bed is fitted with a central oxygen supply system, enabling firefighters to inhale oxygen during afternoon rests and nighttime sleep to better adapt to the high-altitude hypoxic environment. Firefighters began their regular duty after one month of exposure to the high altitude without experiencing any physical discomfort, indirectly indicating that they had acclimatized well to the high-altitude environment.[28] Chronic stress that firefighters are long-term exposed to may lead to adverse physical effects, including sleep disorders.[29] Similar studies in the western high-altitude regions of China are still lacking. In the present study, we observed that the sleep quality of Han Chinese firefighters significantly decreased with increasing altitude (see Table 2). At 500 m, the prevalence of poor sleep quality of the Han Chinese firefighters was 23% using the criteria of the PSQI score >5. This is higher than the general population in China. In a meta-analysis,[30] including ten studies that used the PSQI >7 to assess insomnia, the pooled prevalence of insomnia in the general population of China was 15.0% (95% Confidence interval: 12.1–18.5%), and no significant difference was found in the

prevalence between genders or across the time period. This difference is understandable because we use a PSQI score greater than 5 to indicate poor sleep quality, whereas de Souza et al used a PSQI score greater than 7 to indicate insomnia. Our results were lower than those of Liu et al,[9] who reported a sleep disturbance prevalence of 59.49% among firefighters with a mean service length of 4.79 years. In contrast, 90% of firefighters in our study had less than 1 year of service, which may explain the discrepancy. In our high-altitude study, we found that the sleep quality of Han Chinese firefighters decreased with increasing altitude. Although there was no statistically significant difference in PSQI scores among Han Chinese firefighters across different altitude, the prevalence of poor sleep quality showed a trend toward statistical significance between 500 m and 4509 m (23% vs 44%, $p = 0.08$). After excluding the 500m Han Chinese firefighter sample, correlation analysis suggested a positive trend between PSQI scores and altitude ($p = 0.07$). Although logistic regression analysis did not confirm an effect of high altitude on sleep quality, this may be related to the limited altitude gradient included in this study. In our previous study, we observed that a high-altitude environment affects participants' subjective sleep quality using the Athens Insomnia Scale to assess the sleep quality over the short and long term,[31] and the prevalence of insomnia reached 44% among the young Chinese men who had lived at least six months at 3658 m altitude. The primary factor influencing sleep quality at high altitudes is hypoxia,[32] as the partial pressure of inhaled oxygen decreases with increasing elevation. Research shows that subjects display tidal-like breathing patterns under simulated high-altitude hypoxia. This condition apnea, worsening hypoxemia, which leads to heightened respiratory drive and arousal, disrupting sleep.[3] The specific pathophysiological mechanisms of poor sleep quality at high altitude require further research.

Interestingly, the sleep quality of the Tibetan firefighters did not change significantly with the increase in high altitude (Table 2). A recent study by Song et al[33] found that Tibetans living at altitudes of 2500–2999 m and 4000–4499 m had similar PSQI scores (6.15 ± 2.96 versus 5.70 ± 2.97), but did not report the prevalence of insomnia at these altitudes. Using a PSQI cutoff greater than 7, they found an overall insomnia prevalence of 24% among Tibetans aged 20 to 57 years living at 2500 to 4999 m. The age of subjects in their study was significantly higher than in ours.

Notably, our results show that Han Chinese firefighters have poorer sleep quality than Tibetan firefighters at high altitude (Table 2). At an altitude of 4509 m, the PSQI scores and the prevalence of poor sleep quality among Han Chinese firefighters were significantly higher than those of Tibetan firefighters. Currently, there is limited research comparing the sleep quality of Han Chinese firefighters and Tibetan firefighters; some studies on other occupational groups have been published. Song et al found that the sleep quality (measured by the PSQI) of Han ethnic government workers in high-altitude areas is poorer than that of Tibetans.[33] Similarly, Kong et al showed that Han Chinese soldiers at high altitude have worse sleep quality (also evaluated using the PSQI) compared to native Tibetan soldiers.[32] Li et al's small-sample study showed that sleep quality, measured with a polysomnograph, and nocturnal blood oxygen saturation were poorer in Han Chinese young adults living at high altitudes compared to Tibetan young adults.[34] In the logistic regression analysis, we further demonstrated that Han firefighters have a 3.0 times higher risk of poor sleep quality compared to Tibetan firefighters (Table 3). Certain genes contribute to differences in high-altitude adaptation between the Han Chinese and Tibetan populations.[35–37] We therefore speculate that the difference in sleep quality between Han Chinese and Tibetan firefighters in high-altitude regions may be linked to specific genetic variants. Whether genetic variation is the mechanism underlying the sleep differences between Han Chinese and Tibetan firefighters in high-altitude areas still requires further research to confirm.

In the present study, we observed that the PSQI scores of firefighters were positively correlated with their GAD-7 scores and PHQ-9 scores. The GAD-7 and PHQ-9 scores for the Han Chinese firefighters were higher than those for the Tibetan firefighters, and some of these differences reached statistical significance (see Table 2). Additionally, higher GAD-7 scores were identified as independently associated factors for poor sleep quality through adjusted logistic regression analysis (see Table 3). It is not surprising that firefighters often report high rates of mental health disorders, as they regularly face significant physical, emotional, and psychological challenges.[7] Research indicates that firefighters are substantially more likely to experience depression and anxiety compared to the general population.[8,38–40] Research has shown that while anxiety is linked to disturbed sleep, this relationship is reciprocal rather than causal.[41] Data from the National Canadian Mental Health Survey revealed that firefighters with insomnia were 7 times more likely to suffer from GAD compared to those without insomnia.[42] Therefore, intervening in anxiety and depression of high-altitude

firefighters may hold certain significance for improving sleep quality, especially for Han Chinese firefighters. Additionally, improving sleep quality also benefits the alleviation of anxiety symptoms. Further research is needed to verify these hypotheses.

Limitations

The strength of this study resides in its focus on firefighters, a population at heightened risk of experiencing poor sleep quality, an area that has been underexplored in the western high-altitude regions of China. However, the study's cross-sectional design presents a limitation, as it can identify relationships between factors and sleep quality but cannot establish causation. Additionally, due to cultural and lifestyle differences, there are no Tibetan firefighters at an altitude of 500 m. We included data on Han Chinese firefighters at an altitude of 500 m as a baseline for comparison with the high-altitude data. This clearly illustrates the trend in how altitude affects the sleep quality of Han Chinese firefighters. Had we possessed data on Tibetan firefighters at 500 m, our findings might have been even more compelling. Likewise, the number of Han Chinese firefighters at 4509 m is relatively low due to the harsh high-altitude conditions and varying acclimatization capabilities. It should be noted that, as this study is based on real-world data, its small sample size limits the precision and reliability of the regression estimate for ethnicity; therefore, the results should be interpreted with caution until they are replicated in larger cohorts. Polygraphic sleep monitoring is the objective gold standard for evaluating sleep quality. Due to limitations in research time and funding, this method was not included in our study. Although the PSQI, GAD-7, and PHQ-9 are internationally recognized self-report questionnaires, they may introduce reporting bias, which could affect the interpretation of results. Due to the actual conditions of the high altitude, this study did not include female participants, which may introduce gender bias. These limitations should be addressed in future research.

Conclusion

The study shows that Han Chinese firefighters in this field sample across these stations have worse sleep quality compared to Tibetan firefighters, with higher GAD-7 scores being an independently associated factor for poor sleep quality. More research with females, larger samples, and with designs that better isolate altitude exposure and operational conditions is needed to confirm these results and to explore the mechanisms and long-term effects of poor sleep on firefighter health. Finding ways to improve sleep quality and anxiety symptoms is crucial for developing strategies that support the well-being of high-altitude firefighters, especially for the Han Chinese group.

Data Sharing Statement

Data will be made available on reasonable request from the corresponding author.

Ethics Approval Statement

The study was conducted following the Declaration of Helsinki and approved by the General Hospital of Western Theater Command of the People's Liberation Army (Approval Identifier: 2025EC11-ky070). All participants signed informed written consent and could freely withdraw from the study at any time.

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Author Contributions

Xugang Tang: conceptualization, methodology, data curation, formal analysis, writing-original draft.
Luxun Tang: investigation, data curation, resources, writing-original draft.
Shuang Li: conceptualization, formal analysis, writing-review & editing.
Xuedong Gu: investigation, data curation, writing-original draft.
Xue Li: investigation, data curation, writing-original draft.
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Wen Jiang: data curation, formal analysis, writing-original draft.
Qiang Wang: conceptualization, formal analysis, writing-review & editing.
Yongjian Yang: conceptualization, data curation, formal analysis, funding acquisition, methodology, project administration, resources, supervision, validation, visualization, writing-review & editing.

All authors took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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