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ABSTRACT

Objective Strategies and measures for fighting occupational stress in China are inadequate. This study aimed to determine the level of occupational stress in coal miners and to assess the associations between occupational stress and job burn-out, depression and hypertension. The results could provide clues for preventive measures and strategies to improve the psychological well-being of this population.

Design Cross-sectional study.

Setting Xinjiang Coal Administration Bureau.

Participants Four coal mines were selected randomly (computer-generated random number-based selection process) from the 21 coal mines of Xinjiang, and all miners with >1 year of employment were screened for participation.

Primary and secondary outcome measures A general demographic questionnaire, the Self-rating Depression Scale, the Effort–Reward Imbalance (ERI) model and the Maslach Burn-out Inventory.

Results A total of 1400 questionnaires were collected, including 1334 (95.3%) valid questionnaires. This survey indicated that 1107 (83.0%) participants with an ERI score >1 (high occupational stress) and 227 (12.8%) had ERI ≤1. Severe depression was found in 21.7% of the participants. Job burn-out was positively correlated with occupational stress, which was, in turn, associated with depression. Multivariable linear regression analysis showed that depression ($\beta=0.006$, $p=0.012$), sex ($\beta=0.358$, $p<0.001$) and occupational stress ($\beta=0.702$, $p<0.001$) were independently associated with job burn-out. Working years ($\beta=-0.086$, $p=0.015$) and job burn-out ($\beta=0.022$, $p<0.001$) were directly associated with depression.

Conclusion This study highlights that occupational stress may affect job burn-out, depression symptoms and hypertension. A higher degree of occupational stress was associated with poorer mental status and hypertension.

INTRODUCTION

There is a high demand for workers given the recent economic development and technological progress in China, and workers increasingly feel pressure.¹ Occupational stress refers to job demands beyond one's working resources, abilities and needs, and

Strengths and limitations of this study

- Even though it was a cross-sectional study, a randomised sampling method was used.
- The study population is homogeneous, and the sample size is large.
- Valid and reliable questionnaires (validated in Chinese) were used, decreasing the bias.
- The cross-sectional design prevented the determination of causal relationships.
- Social support and organisation and family backgrounds were not assessed. Not all job types related to coal mining were examined.

when employees are exposed to harmful physical and emotional environments. It is commonly experienced in response to several adverse conditions related to the working environment and has attracted increasing attention in the recent years.² The mental and hypertension outcomes of workers are affected by extended periods of work pressure caused by occupational stress through non-specific pathways,³ including the cardiovascular, central nervous system and immune system diseases. Other effects include reduced concentration, decreased working efficacy and sleep disturbances.^{4 5} More importantly, some coal mining accidents are caused by occupational stress.⁶ According to the American Institute of Stress, occupational stress is responsible for 80% of all work-related injuries and 40% of workplace errors, while 30% of European staff and workers experience the effects of work-related stress.⁷ A systematic review demonstrated that 22% of workers with high-risk responsibilities experience occupational stress.⁷ Stress is a significant part of the living conditions of coal miners, correlating with harsh working conditions, including repetitive activities, lifting heavy materials, shift

work and night work.⁸ Besides, job burn-out results from working stress, and inappropriate work environment can trigger depression.⁹ In addition, a study revealed average rates of 18.6%, 26.4% and 23.5% for hypertension, hyperlipidaemia and hyperglycaemic, respectively, in coal miners.¹⁰ Therefore, hypertension should be evaluated in relation to working conditions.

Between 2010 and 2014, there were almost 4.7 million coal miners in China.⁶ Xinjiang is one of the main coal deposits and is employing a large number of coal miners. Coal miners involved in underground work have a degree of mental burden score of 8.3, representing one of the heaviest mental burdens among 150 occupations.¹¹ Due to the high labour intensity and a dangerous working environment, coal miners are at risk of mental diseases, and limited working hours and hard labour also increase occupational stress in this population.^{12 13} A report revealed that some coal miners become agitated due to chronobiological disorders caused by shift working and repetitive ancillary activities such as changing clothes and getting lamps.¹⁴ Moreover, an online survey of coal miners revealed that mental health problems induced by mental stress should not be neglected.¹⁵

Occupational health research in China remains limited, and strategies and measures for combating occupational stress are inadequate. In China, the focus is placed on lung diseases in coal miners, neglecting mental health.¹⁶ Internationally, only a few studies have investigated occupational stress and mental health due to strict legislation of coal mine safety. It was found that organisational policy and training quality are the main sources of mental pressure.¹⁷ Meshi *et al* demonstrated that factors aggravating occupational stress in coal miners include the imbalance between payout and return, as well as irregular working schedule and shift working.¹⁴

Therefore, the levels of occupational stress, job burn-out, depression and hypertension in coal miners, as well as the relationships among them, are poorly known. China's coal accounts for about 13.9% of the world's total amounts, and Xinjiang is one of the main sources of Chinese coal.¹⁶ Coal miners' health is closely associated with the rapid development of the national economy. Coal miners represent a special group of workers. They work for a long time in the dark, damp underground, under a high degree of danger, which is conducive to suffer from occupational stress. There is little research on the physical and mental health of coal miners in China and around the globe. Most available research focused on lung disease, but less on other diseases, especially mental health. In order to provide preventive strategies and evidence for improving the mental status and hypertension in coal miners, this study aimed to determine the level of occupational stress in coal miners and to assess the associations between occupational stress and job burn-out, depression and hypertension.

METHODS

Participants

This cross-sectional study was carried out between March and December 2018. The target population included all coal miners of the Xinjiang Coal Administration Bureau. There are 21 coal mines and almost 200 000 employees performing work related to the coal industry in Xinjiang Province. Four coal mines were selected randomly (computer-generated random number-based selection process) from the 21 coal mines of Xinjiang. The four mines included a large coal company (annual production >120 t) and a small coal company (annual production <30 t) in northern Xinjiang, and a large coal company (annual production >120 t) and a small coal company (annual production <30 t) in southern Xinjiang. All workers were screened for participation. The inclusion criteria were: (1) between 18 and 60 years of age and (2) >1 year of employment. Participants with a diagnosis of mental disorder were excluded. All participants provided written informed consent.

Patient and public involvement

No patients involved.

Measurement parameters

The field questionnaire survey method was adopted. After the physical examination of coal miners, a centralised questionnaire survey was conducted, and the questionnaire forms were collected on the spot. The questionnaire consisted of four parts, including basic information, the Effort–Reward Imbalance (ERI) questionnaire, the Self-Rating Depression Scale (SDS). This survey used a self-filling questionnaire. Since the education level of coal miners is relatively low, in order to ensure the accuracy of the questionnaire, the filling methods and standards are described at the top of the questionnaire. The quality of the filled questionnaire was checked by the investigators, supplementing missing items.

The general demographic characteristics included sex, age, working age, educational background, type of work, marital status, income, and smoking and drinking statuses. The participants were asked to answer 'yes' or 'no' to a drinking statuses regarding whether they drink (self-reported) .

Effort–Reward Imbalance

To assess occupational stress, the Chinese version of the ERI questionnaire¹⁸ was completed by the participants. This questionnaire theoretically detects whether the individual's work effort is equal to the reward. It contains three modules consisting of 23 items in total, including working effort (6 items), working reward (11 items) and working engagement (6 items). Participants responded to every item on a five-point scale ranging from 1 (never) to 5 (always). A total score was calculated for each participant. A tense state referred to high effort and low reward according to the ERI scale, while low effort and high reward indicated no occupational stress. In terms

of score, ERI >1 indicated high effort and low reward, ERI=1 suggested balanced effort and reward, and ERI <1 indicated high reward and low effort. The higher the ERI score, the higher the level of occupational stress. In addition, a higher working effort score indicates a heavier working load.¹⁹

Job burn-out

The Maslach Burn-out Inventory (MBI) questionnaire was used to assess job burn-out symptoms. It contains three parameters, including emotional exhaustion, depersonalisation and reduced accomplishment.²⁰ Emotional exhaustion refers to physical and emotional depletion caused by weary and worn-out states, including fatigue, exhaustion and worries, brought by work to the emotional state. Depersonalisation reflects a poor social relationship and an indifferent, negative attitude to work. Reduced accomplishment indicates that an individual has a negative self-assessment of work accomplishment, that is, a sense of incompetence and a lack of work achievement or working efficiency. Each parameter consists of five items, for a total of 15 items. MBI has high reliability and validity. Three critical values^{11 16 21} delineate four levels of job burn-out, namely, no burn-out (scores below the respective critical values^{11 16 21} in all three parameters), mild burn-out (scores no lower than the respective critical values in any parameter); moderate burn-out (scores no lower than the respective critical values in any two given parameters) and severe burn-out (scores no lower than the respective critical values in all three parameters).

Depression

The SDS compiled by Sirodoff in 1977 was used to evaluate depression symptoms.²² The scale has 20 items, with the three-rank estimate system applied based on the frequency of symptoms or feelings over the past week. More specifically, 0 refers to no symptoms, 1 to seldom symptoms, 2 to frequent symptoms and 3 to permanent symptoms. The critical value for the SDS is a score of 16. Thus, participants with scores >16 were considered to be experiencing depression symptoms. More importantly, four levels of depression were determined: no (<16), mild (16–19), moderate (20–23) and severe (≥24).²³

Physical health examination

Following occupational health regulations, 508 of the current subjects had health examination by the Xinjiang Occupational Health Examination Organisation, assessing parameters such as body mass index (BMI) and blood pressure.

Hypertension was screened during the mandatory routine physical examinations. Blood pressure was measured as follows. After the medical staff calibrated the arm-type electronic blood pressure metre, the examinee sat straight with the elbow and heart at the same level. Blood pressure in the right arm was measured twice and averaged. In case of a difference exceeding 5 mm Hg between the two values, the examinee had to rest for

5 min before a retest, and the final blood pressure was the average value of the three measurements. After the first examination, the workers suspected of hypertension were followed twice within 3 weeks after the first physical examination. Diagnostic criteria for hypertension were: systolic blood pressure ≥140 mm Hg and/or diastolic blood pressure ≥90 mm Hg.²⁴

According to the 2007 edition of the guidelines for prevention and control of overweight and obesity in Chinese adults²⁵ standard and calculation method: BMI (kg/m²)=weight (kg)/height² (m²). BMI <18.5 kg/m² is underweight, BMI 18.5–23.9 kg/m² is normal, BMI 24.0–27.9 kg/m² is overweight and BMI ≥28 kg/m² is obese.

Quality control

All study procedures adhered to Good Clinical Practices. Before the formal survey, occupational and mental health researchers revised the questionnaires. Before the formal investigation, 50 first-line coal miners from Shenhua coal mine in Xinjiang were selected for a preliminary investigation to test the questionnaires. All data were double entered, and any discrepancy in the database comparison was corrected based on the original paper documents.

Statistical analysis

All data were collected with Epidata V.3.1, and statistical analyses were performed with SPSS V.17.0 (IBM). Continuous variables were presented as means±SD, and group pairs were compared by the Student t-test. Categorical data were expressed as n (%), and the X² test or Fisher's exact test was used for comparison. Correlations were tested using the Pearson or Spearman correlation analysis. Multivariable analysis was performed by multiple linear regression. The significance level was p<0.05.

RESULTS

Participant characteristics

A total of 1400 questionnaires were distributed, and 1344 were returned, for a recovery rate of 95.3%. The participants were 42.2±8.6 years old, with a median of 31.5 (1, 42) working years. The demographic characteristics are shown in [table 1](#). No participants were excluded due to a mental disease.

The patients were divided into two groups based on occupational stress levels, and there were 1107 (83.0%) participants with an ERI score >1, and 227 (12.8%) had ERI ≤1 (there were 56 (4.2%) participants with ERI=1). As shown in [table 1](#), there were statistically significant differences between the two groups in sex, age, working years, level of education and annual income (X² test, all p<0.05). These findings indicate that longer working years, higher educational level, marriage, lower annual income, and male sex were associated with occupational stress.

Table 1 Demographic characteristics of the included coal miners by occupational stress level indicated with Effort–Reward Imbalance (ERI) score (n=1334)

	Total (n=1334)	ERI >1 (n=1107)	ERI ≤1 (n=227)	P value
Sex, n (%)				<0.001
Male	1173 (87.9)	1040 (88.6)	133 (11.4)	
Female	161 (12.1)	67 (41.6)	94 (58.4)	
Age, n (%)				0.024
≤30	202 (15.1)	158 (78.2)	44 (21.8)	
31–45	575 (43.1)	470 (81.7)	105 (18.3)	
>45	557 (41.8)	479 (86.0)	78 (14.0)	
Working years, n (%)				<0.001
≤15	623 (46.7)	488 (78.3)	135 (21.7)	
>15	711 (53.3)	619 (87.1)	92 (12.9)	
Work type, n (%)				0.073
Coal digger	266 (19.9)	222 (83.5)	44 (16.5)	
Driver	72 (5.4)	55 (76.4)	17 (23.6)	
Electrical fitter	274 (20.5)	235 (85.8)	39 (14.2)	
Hauler	94 (7.0)	74 (78.7)	20 (21.3)	
Safety worker	211 (15.8)	165 (78.2)	46 (21.8)	
Ground	417 (31.3)	356 (85.4)	61 (14.6)	
Working shift, n (%)				0.900
Fixed the day	476 (35.7)	398 (83.6)	78 (16.4)	
Work on two shifts	203 (15.2)	168 (82.8)	35 (17.2)	
Three shifts	655 (49.1)	541 (82.6)	114 (17.4)	
Level of education, n (%)				<0.001
Middle school or below	671 (50.3)	486 (72.4)	185 (27.6)	
Middle school above	663 (49.7)	621 (93.7)	42 (6.3)	
Marital status, n (%)				0.143
Spinsterhood	138 (10.3)	107 (77.5)	31 (22.5)	
First marriage	1153 (86.4)	966 (83.8)	187 (16.2)	
Other	43 (3.2)	34 (79.1)	9 (20.9)	
Annual income, n (%)				0.003
≤60 000	1116 (83.7)	941 (84.3)	175 (15.7)	
>60 000	218 (16.3)	166 (76.1)	52 (23.9)	
Smoking, n (%)	725 (54.3)	602 (83.0)	123 (17.0)	0.957
Drinking, n (%)	783 (58.8)	650 (83.0)	133 (17.0)	0.972

Underground work professionals included coal diggers, drivers, electrical fitters, haulers and safety workers. Other marital statuses included remarriage, divorce and widowed.

$P < 0.05$

Mental health and hypertension in coal miners

In this study, there were 631 (47.3%), 397 (29.8%), 180 (13.5%) and 126 (9.4%) coal miners with no, mild, moderate and severe burn-out levels, respectively (table 2). All participants with job burn-out of mild and moderate level had ERI >1. The ERI score of participants with severe job burn-out in the ERI ≤1 group were all equal 1. In other words, all participants with ERI <1 had no job burn-out. Therefore, there were significant differences in

job burn-out levels between coal miners with ERI >1 and ERI <1 ($p < 0.001$), indicating that coal miners with occupational stress had a higher job burn-out level (table 2).

The depression status of coal miners was divided into four levels (no, mild, moderate and severe). As shown in table 2, 82.2% (mild), 91.7% (moderate) and 83.0% (severe) coal miners with depression were in the ERI >1 group. These data indicated significant differences in depression between the ERI >1 and ERI <1 groups

Table 2 Occupational stress level indicated by Effort-Reward Imbalance (ERI) score in relation to depression, job burn-out and hypertension

	Total	ERI >1	ERI ≤1	P value
	(n=1334)	(n=1107)	(n=227)	
Depression, n (%)				
No	452 (33.9)	330 (73.0)	122 (27.0)	<0.001
Mild	73 (5.5)	60 (82.2)	13 (17.8)	
Moderate	520 (39.0)	477 (91.7)	43 (8.3)	
Severe	289 (21.7)	240 (83.0)	49 (17.0)	
Job burn-out, n (%)				
No	631 (47.3%)	460 (72.9)	171 (27.1)	<0.001
Mild	397 (29.8)	397 (100)	0 (0)	
Moderate	180 (13.5)	180 (100)	0 (0)	
Severe	126 (9.4)	70 (55.6)	56 (44.4)	
Hypertension				
Yes	182 (35.8)	159 (87.4)	23 (12.6)	0.204
No	326 (64.2)	271 (83.1)	55 (16.9)	

$P < 0.05$

($p < 0.001$), indicating that coal miners with occupational stress had a higher depression level (table 2). There were 182 (35.8%) participants with hypertension. There was no significant difference between the ERI >1 and ERI ≤1 groups in hypertension prevalence (table 2).

Risk factors for job burn-out and depression in coal miners

In the multivariable linear regression model, job burn-out and depression score of coal miners were entered as the dependent variable, and other parameters as independent variables, including sex, age, working years, educational level, work type, marital status, work shift, annual income and ERI and depression scores. The analysis indicated that the ERI score ($\beta = 0.702$, $SE = 0.04$; $p < 0.001$), sex ($\beta = 0.358$, $SE = 0.077$; $p < 0.001$) and depression score ($\beta = 0.006$, $SE = 0.002$; $p = 0.012$) were independently associated with job burn-out. These data indicated that male coal miners with high ERI score and depression scores had a greater risk of job burn-out. Two factors directly contributed to depression, including job burn-out score ($\beta = 0.022$, $SE = 0.002$; $p < 0.001$) and working years ($\beta = -0.086$, $SE = 0.035$; $p = 0.015$) (table 3).

Risk factors for hypertension

Before logistic regression analysis, a X^2 test was performed with possible relevant variables (online supplementary table S1). In this analysis age, working type, working shift, degree of education, marital status, annual income, smoking status, drinking status, BMI, ERI, job burn-out and depression. In this analysis, age, working type, working shift, drinking status, BMI, ERI and depression showed statistical significance and were included in the multivariable analysis (online supplementary table S1).

The logistic regression model revealed that drinking (OR 2.55, 95% CI 1.30 to 5.0; $p = 0.006$), ERI >1 (OR 3.03, 95% CI 1.67 to 5.52; $p < 0.001$), age >45 (OR 8.39, 95% CI 3.53 to 19.95; $p < 0.001$), work on two shifts (OR 0.32, 95% CI 0.15 to 0.69; $p = 0.004$), overweight (OR 0.27, 95% CI 0.14 to 0.53; $p < 0.001$), mild depression (OR 4.10, 95% CI 1.96 to 8.59; $p < 0.001$) and severe depression (OR 3.17, 95% CI 1.31 to 7.65; $p = 0.01$) were risk factors for hypertension (table 4).

Table 3 Multivariate linear regression analysis of factors associated with mental health (n=1334)

	β	SE	P value
Job burn-out			
ERI score	0.702	0.040	<0.001
Male	0.358	0.077	<0.001
Depression	0.006	0.002	0.012
Depression			
Job burn-out score	0.022	0.002	<0.001
ERI score	-0.016	0.05	0.755
Working years	-0.086	0.035	0.015

All included variables were sex, age, working years, level of education, work type, marital status, working shift, annual income, and ERI score and depression score.
ERI, Effort-Reward Imbalance.

Table 4 Multivariable logistic regression analysis on influencing factors of hypertension (n=508)

	OR	95% CI	P value
Age			
≤30	Ref		
31–45	2.34	0.98 to 5.58	0.055
>45	8.39	3.53 to 19.95	<0.001
Working types, under ground			
Working shift			
Fixed the day	Ref		
Work on two shifts	0.32	0.15 to 0.69	0.004
Three shifts	1.44	0.87 to 2.41	0.16
Drinking, yes	2.55	1.30 to 5.00	0.006
BMI			
underweighted	0	0.000 -	1
Normal	Ref		
Overweight	0.27	0.14 to 0.54	<0.001
Obesity	1.34	0.60 to 2.98	0.47
ERI >1	3.03	1.66 to 5.52	<0.001
Depression			
No	Ref		
Mild	4.10	1.96 to 8.59	<0.001
Moderate	0.74	0.35 to 1.57	0.436
Severe	3.17	1.31 to 7.65	0.01

P<0.05
BMI, body mass index; ERI, Effort–Reward Imbalance.

DISCUSSION

In this study, the ERI score was significantly associated with job burn-out and depression score, indicating that occupational stress significantly contributed to job burn-out and depression. In addition, the depression score was associated with job burn-out, suggesting that workers suffering from depression were more likely to experience job burn-out.

The present study strongly suggests that occupational stress is associated with job burn-out, depression symptoms and hypertension in coal miners. The higher the degree of occupational stress, the poorer an individual's mental status and blood pressure. Such relationships were already described in various occupations, but coal miners represent a special group of workers. They work for a long time in the dark, damp underground, under a high degree of danger, which is conducive to suffer from occupational stress. Most available research focused on lung disease, but less on other diseases, especially mental health. Nevertheless, this highlights that the results of the present study have limited generalisability. Indeed, the results might apply only to miners or to individuals working in solitary, isolated locations and under extreme and dangerous conditions. Additional studies will be

carried out to validate those results in other types of mining and other countries, especially in the context of a trend toward a lower use of coal as a fuel around the globe.

With economic and social development, work conditions and working procedures have changed dramatically, and workers increasingly experience stress due to complex work environments with high requirements and challenges. These include a high pace of life, fierce competition, complex interpersonal relationships and risk of a variety of diseases.^{20–22} Occupational stress is a complex phenomenon resulting from various factors, including molecular biology, occupational health and environmental health.²¹ Occupational stress not only arises from factors including occupational characteristics, interpersonal relationships, human resources, working methods, hazardous substances, and so on, but also involves personal characteristics, family status and culture. This study indicated that coal miners in Xinjiang suffered from occupational stress. The associated factors were working years, educational status, marital status, annual income and sex. The male coal miners involved in this study worked underground in a moist, hot environment; besides, they earned little money to support their families. In China, married individuals with low annual income more easily develop occupational stress since they provide for the whole family, especially coal miners from the countryside. As shown above, participants with a high education level may easily develop occupational stress since they long to engage in creative work, requiring updated technical and working skills.

Burn-out represents a psychological syndrome resulting from a prolonged response to chronic interpersonal stressors at work and manifests as pronounced exhaustion, development of cynical attitudes and feelings, and a sense of ineffectiveness and lack of accomplishment.²⁶ This survey found that more than one half of coal miners suffered from job burn-out. Most of the job burn-out were attributed to occupational stress, and job burn-out increased with the ERI score. These results were consistent with a study assessing occupational stress in doctors and nurses.²⁷ Job burn-out is promoted by long-term occupational stress. Sometimes, job burn-out is caused by tedious tasks that may suppress interest in work. Meanwhile, job burn-out results in a negative attitude towards work and indifference to interpersonal relationships.¹⁸ It is known that tense interpersonal relationships, heavy workload and life pressure contribute to nervous tension.²⁸ The multivariable linear regression in this study revealed that occupational stress, sex and depression were associated with job burn-out, which results from prolonged work under pressure. Mental health status is altered by psychological modifications induced by long-term and chronic pressure reactions.²⁹ As shown above, males had higher job burn-out levels than females. Depression and burn-out may have similar causes at the biological level. Indeed, Bakusic *et al* demonstrated that burn-out and depression likely have a common biological basis, that is,

DNA methylation, which may represent a biomarker of stress-related mental illnesses, including depression and burn-out.³⁰ Nevertheless, it should be mentioned that the ERI score had no significant association with depression ($\beta=-0.016$, $p=0.755$) in this study.

Mirmohammadi *et al.*³¹ suggested that occupational stress induces hypertension, hyperlipidaemia and coronary heart disease, in addition to reducing labour efficiency and quality of life. In this study, 508 coal miners underwent health examinations, and the main disease was hypertension, in agreement with previous findings.³² These results suggest that the prevention and treatment of cardiovascular diseases should be performed for coal miners. The above associations of hypertension with job burn-out could be explained by that job burn-out is an extreme form of prolonged occupational stress.³³ Continuous stimulation of the stress state can activate the sympathetic nerve-adrenal medullary axis and release large amounts of catecholamine through the psychology neuroendocrine mechanism, which promotes the secretion of adrenalin and causes the corresponding changes in physiological functions.³⁴

Recently, psychological problems in professionals (eg, depression, psychological disorder and anxiety) have sparked concern, with depression representing one of the most common mental health issues and showing a high incidence.³³ Depression has a negative effect on both society and individuals; more importantly, it causes financial loss and reduces productivity.³⁵ This study demonstrated that of the coal miners had severe depression. In addition, the rate of depression in coal miners with occupational stress was higher than that of the occupational stress-free counterparts, corroborating a previous report.³⁶ The multivariable linear regression analysis showed that ERI, working years and job burn-out were independently associated with depression. Individuals with high occupational stress levels more easily developed job burn-out, which is consistent with findings by Shen *et al.*³⁷ Evidence suggests that elevated job burn-out does not only increase the incidence rates of depression and anxiety but also may cause physical diseases.¹⁸ In this study, coal miners with more than 15 years of employment had tolerated boring and repetitive tasks for a long time; in addition, an adverse working environment (darkness and humidity) negatively affected their mental health. Furthermore, such jobs are defined by constant physical requirements and pressures, which further affect mental health negatively.³⁸

The limitations of this survey should be mentioned. First, even though a randomised sampling method was adopted, each cluster should be more specifically assessed. Second, social factors, that is, living environment, social support, organisation and family background were not considered. Third, this study only considered coal diggers, drivers, electrical fitters, haulers, safety workers and ground staff, not including other types of mine workers. In addition, the present study did not compare the occupational levels of coal miners with that

of non-miners. Fourth, this cross-sectional study could not reveal the causal associations among occupational stress, job burn-out, depression and hypertension. A cohort study is underway to investigate occupational stress-triggered mental disorders in coal miners of Xinjiang. This will provide additional insights into the importance of eliminating stress and mental health in coal miners.

The present cross-sectional study cannot help determine cause-to-effects among burn-out, depression, job pressure and hypertension. Nevertheless, the present study revealed the deleterious effects of occupational stress on miners. Accordingly, a previous study showed that coal miners in Brazil suffered from anxiety and poor sleep quality.³⁹ A study in China indicated that coal miners had depressive symptoms that could be predicted by occupational, psychological factors.⁴⁰ In the USA, the prevalence of obesity and hypertension was reported to be high among coal miners.⁴¹ The underground environment was identified as being an important cause of hypertension.⁴² The present study expands those previous studies by indicating that a higher degree of occupational stress was associated with poorer mental status and hypertension. It also provides the characteristics of those suffering from occupational stress in the coal miner population. Therefore, available occupational stress counselling and management could ultimately be tailored to this specific population. This calls for the development of national policies on the matter that could improve the quality of life and mental and physical health of coal miners. Nevertheless, the aim of the present study was not to develop such strategies. This will have to be examined in future studies. In this light, the study of the causal relationships among occupational stress, job burn-out, depression and hypertension is necessary.

In conclusion, this survey indicated that 87.2% of coal miners in Xinjiang suffered from occupational stress. ERI >1 was mainly reported by married males with more than 15 years of employment, high education level and annual income below 60 000 Yuan. Coal miners with occupational stress had high burn-out and depression scores, indicating that occupational stress promotes job burn-out and depression. Therefore, occupational stress requires interventions via prevention with valid policies and an optimal workplace environment. This would result in an improved quality of life of workers and reduced rates of mental and cardiovascular diseases.

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Contributors XY, XS and XM carried out the studies, participated in collecting data and drafted the manuscript. JL and XY performed the statistical analysis and participated in its design. XG, ZZ and HG participated in the acquisition, analysis or interpretation of data and drafted the manuscript. All authors read and approved the final manuscript.

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Patient consent for publication Not required.

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Data availability statement All data relevant to the study are included in the article or uploaded as online supplementary information. The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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