Study on the Relationship Between Musculoskeletal Disorders, *BDNF* Gene, *TPH-2* Gene, and Mental Health in Coal Mine Workers in China

Ting Jiang

Xinjiang Medical University

Xue Li

Xinjiang Medical University

Qiaoyun Xue

The First Affiliated Hospital of Xinjiang Medical University

Jiwen Liu (✉ liujiwen123123@126.com)

Xinjiang Medical University

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Abstract

Background: Coal is the core energy source of the global energy system. To ensure the sustainable development of the coal industry, the mental health of coal miners is crucial.

Methods: This cross-sectional study was conducted between August 2018 and June 2019. A total of 1,675 coal miners were surveyed using the Musculoskeletal Disorders (MSDs) Questionnaire and the Symptom Checklist-90 (SCL-90). At the same time, polymorphisms in the BDNF gene (rs6265, rs10835210) and TPH2 gene (rs4570625, rs4131347) in whole blood DNA were detected to analyze the influence of a gene-environment interaction on mental health.

Results: The results showed that the mental health status of coal miners was poorer than the Chinese norm ($P < 0.05$). The mental health status of workers with MSDs was lower; MSDs interact with the BDNF gene rs6265 and TPH2 gene rs4570625, which affects mental health.

Conclusions: It is suggested that employers should improve the working environment of workers, shorten the working time, pay attention to the mental health of workers, and provide timely psychological counseling to workers who suffer from mental health problems, so as to improve workers' mental health and working ability, as well as their quality of life.

Background

Mental health is an important part of human health. Without good psychological health, a healthy life is not possible. In recent years, the global mental health movement developed rapidly, and the level of social attention that is paid to mental health has reached new heights. Researchers have carried out studies to examine various factors related to the mental health of teachers, police, medical personnel, and other groups [1–3]. Studies have shown that the mental health of the occupational population is not optimal due to poor work environments and work-related stress[4].

In addition to demographic characteristics, the working and living environment, and other factors affecting mental health, studies have found that the effect of gene polymorphisms on mental health cannot be ignored [5]. Brain-derived neurotrophic factor (*BDNF*) is a mediator of neuronal survival and plasticity of dopaminergic, cholinergic, and serotonergic neurons in the central nervous system (CNF) [6]. *BDNF* is involved in use-dependent plasticity mechanisms, such as long-term enhancement and learning, which may play an important role in neuropathology and the treatment of depression [7]. This theory is based mainly on the correlation between stress or antidepressant treatment and the decrease or increase in *BDNF* [8]. Brunoni AR et al. believed that blood *BDNF* was associated with a depression response, and the *BDNF* level in patients with depression was much lower than that observed in normal people: The greater the severity of the depressive symptoms, the lower the *BDNF* level in serum [9]. Tryptophan hydroxylase-2 (*TPH2*) gene is an important factor for the synthesis of 5-HT in the brain, the maintenance of normal 5-HT levels in the brain, and the maintenance of normal transmission by 5-HT in the cortex [10]. Studies have shown that polymorphisms in the *TPH2* gene are associated with depression, and single nucleotide polymorphisms (SNPs) in the *TPH2* gene are associated with major depression [11]. A meta-analysis of studies on the correlation between *TPH2* gene polymorphisms and depression found that all studies on *TPH2* rs7305115 were analyzed by subgroups of Asian countries and

non-Asian countries. Among rs7305115, the GG genotype and G allele in Asian countries also increased the risk of depression [12].

Musculoskeletal disorders (MSDs) are due to occupational exposure risk factors (e.g., repeat operations, poor posture, physical loads, vibration, etc.), and can cause obvious damage to the musculoskeletal system. MSDs are associated with symptoms such as numbness, pain, and restricted movement, and these symptoms tend to last for more than 24 hours. After a period of rest, the patients may have been unable to return to work, and it is necessary to rule out other medical emergencies, physical disabilities, or illness sequelae, as the cause [13]. MSDs are one of the common types of occupational diseases that are found in almost every industry. Due to differences in the characteristics of industries and in the nature of various types of work, the prevalence of MSDs in different industries also varies substantially. MSDs are included in the category of occupational diseases in industrial developed countries, and it is becoming increasingly vital to address the prevention and treatment of MSDs. The World Health Organization (WHO) has shown continuous concern for this issue, encouraging a greater amount of research to be carried out on occupational diseases [14]. Studies have demonstrated that the number of cases of work-related MSDs accounts for more than 60% of the total cases of occupational diseases, and it is the main cause of absenteeism, disability, early retirement, and economic loss [15–16]. According to relevant research data from various countries, MSDs in the working population accounts for more than 50% of the total population [17–19], and the annual medical and compensation costs caused by MSDs reached more than 13–54 billion [20]. Crofford et al.[21] showed that psychological stress can directly cause physiological reactions, such as increased muscle tension, and these reactions may eventually induce musculoskeletal development. Work-related pressure can cause workers to unconsciously assume a forced body posture at work. Workers may not ensure that they get enough rest, and they may experience physical discomfort as a result of maintaining a static posture for a long time, which leads to greater musculoskeletal pressure.

At present, coal remains the core energy-type of the global energy system, and the global demand for coal will remain stable over the next five years. Therefore, in order to ensure the sustainable development of the coal industry, we must pay attention to the health problems of coal miners. The work environment of coal miners and the need to work in an environment that is hundreds of meters underground means that coal miners are subjected to large amounts of dust, noise, vibrations, and humidity, as well as factors that pose occupational hazards, such as poor posture. In addition, years of working in a poor environment have cause coal miners to develop pneumoconiosis, chronic obstructive pulmonary disease COPD, musculoskeletal disorders, and other diseases. Moreover, the underground coal mine environment is highly complex. Water, fire, gas, coal dust, and other factors threaten the safety and lives of coal miners, and as such, these workers are obliged to cope with substantial psychological pressures during their work. Thus far, most studies have investigated the status quo of musculoskeletal disorders, the mental health status, and influencing factors of coal miners, while few studies have analyzed the relationship between musculoskeletal disorders and mental health. However, there are few reports on the influence of the gene-environment interaction on the mental health of coal miners. Therefore, this study constructed a gene-environment interaction model using GMDR(0.9), and analyzed the relationship between musculoskeletal disorders, *BDNF* gene, *TPH2* gene, and mental health, so as to provide a basis for relevant departments to take corresponding measures to improve the mental health of coal miners and improve their quality of life.

Methods

Study population and procedure

This cross-sectional study was conducted from August 2018 to June 2019. According to the main production process of coal mines (i.e., a surface production system and underground production system), stratified cluster sampling was employed to carry out a questionnaire survey among coal miners with more than one year of work experience. Inclusion criteria: The participants who took part in this study were coal miners aged 18-60 years old who had worked for more than one year, volunteered to participate, and provided their written informed consent. Exclusion criteria: Miners who suffered from severe cognitive impairment or who had a previous history of dementia or mental illness were excluded. A total of 1,800 questionnaires were distributed, of which 1,675 were retrieved, with an effective recovery rate of 93.06%. This research scheme was approved by the Ethics Committee of Xinjiang Medical University .

A total of 30% of the sample content was randomly selected as the experimental sample [22], and samples with substandard concentration and purity were eliminated for DNA extraction. Finally, 250 coal miners with psychological disorders were selected as the case group for this experimental study. According to the 1:1 matching principle, 250 coal miners, who did not suffer from any psychological disorder, were selected as the control group. The matching principle was: same sex, same unit, age ± 2 years, and length of service ± 2 years.

Measures

Musculoskeletal disorders investigation

Using the musculoskeletal disorders questionnaire that was jointly developed by Yang Lei et al. [23], the questionnaire was compiled according to the Nordic Musculoskeletal Survey, which divided the body into nine parts: the neck, shoulder, upper back, elbow, lower back, wrist, hip, knee, and foot. The respondents were asked whether they had experienced any discomfort in each part of their body over the past year, and if they had suffered from any discomfort, they were asked if such symptoms were resulted in work absenteeism. The questionnaire was compiled based on the national conditions of China and the research experience of domestic scholars, which was more suitable for the evaluation of MSDs among the Chinese population. The overall Cronbach's α coefficient of the questionnaire was 0.81, showing good reliability and validity [24]. MSDs were determined by the criteria specified by the National Institute of Occupational Safety and Health (NIOSH) for work-related musculoskeletal injury in the United States. When symptoms of discomfort, such as pain, burning, numbness or tingling occur in various muscles and joints of the body, and the following conditions are met at the same time, it can be determined that this body part is affected by musculoskeletal disease [25]: (1) Unwell during the past year, (2) patients started to feel uncomfortable after undertaking the current job, (3) no previous accidents or sudden injuries, etc. (affected parts of discomfort), and (4) the symptoms of discomfort occurred every month or lasted for more than seven days.

Mental health investigation

In this study, the Symptom Checklist-90 (SCL-90) was used to measure mental health [26], which assessed the mental health status of individuals during a one-week period. The scale consists of 10 factors, including somatization, compulsion, interpersonal sensitivity, depression, anxiety, hostility, terror, paranoia, psychosis,

and other items, and it includes a total of 90 items. The scoring method was based on a five-point Likert-type scale, and the score of each item was tabulated to determine the total score of the SCL-90, the higher the score, the poorer the mental health status. The criteria for identifying the presence of psychological disorders was as follows: total score ≥ 160 points or >2 points for any factor [27]. This scale had good reliability and validity[28].

Genotyping

According to the related references and the use of the HapMap database (<http://hapmap.ncbi.nlm.nih.gov/>), this study referred to information concerning SNP genotypes in the Chinese Human Genome (CHB). The current internationally recognized gold standard was applied (i.e., $r^2=0.8$, MAF $>15\%$ standard) and Haploview software (<http://www.broad.mit.edu/mpg>) was used to select the target tag SNP sites. The SNP sites, which were finally screened out in this study, included the following: the *BDNF* gene rs6265 and Chinese genome-wide SNP genotype information with respect to rs10835210, *TPH-2* gene rs4570625, and rs4131347. The target fragment was amplified by polymerase chain reaction restriction fragment length polymorphism (PCR-RFLP), the PCR products were digested with specific endonucleases for SNP typing to detect the polymorphisms in rs6265, rs10835210, rs4570625, and rs4131347 of the *BDNF* gene extracted from whole blood DNA. Table 1.

Table 1. Primer sequences

Primer		Sequence
<i>BDNF</i>		
rs6265	Forward	5'-CTGCTTTCTCCCTACAGTTCCAC-3'
	Reverse	5'-CAAGTCTGCGTCCTTATTGTTTTCT-3'
rs10835210	Forward	5'-GTGGGTAGACGCCAAAAC-3'
	Reverse	5'-GCCTGGAAACTGCCTTACT-3'
<i>TPH-2</i>		
rs4570625	Forward	5'-TTTTATGAAAGCCATTACACAT-3'
	Reverse	5'-TTCCACTCTTCCAGTTATTTTA-3'
rs4131347	Forward	5'-TTGGTCCAGGGTTCACTCAT-3'
	Reverse	5'-TTGTGGCCAAGAACTTTGG-3'

Quality control

Before carrying out the formal investigation, we conducted a small preliminary survey. The investigators were trained uniformly and have medical knowledge. After the respondents completed the questionnaire, it was collected immediately on-site. After the questionnaire was collected, the investigators uniformly numbered the questionnaires and checked the extent to which they had been completed. Questionnaires that contained less than 80% of the content were rejected. During the experiment, the reagent name was carefully checked, the reagent was added in strict accordance with the required dosage, and the experiment time was controlled in strict accordance with the instructions. Samples and reagents were properly stored to avoid degradation and

cross-contamination. During the experiment, the experimental samples were numbered one by one to ensure the correspondence between the experimental samples and the epidemiological investigation samples.

Statistical analysis

The data were entered into the Epidata 3.0 database, SPSS version 21.0 software was used for the statistical analysis. T-tests were performed to compare the mean between the two groups, chi-squared tests were carried out to compare the rates, and unconditional logistic regression was used for multivariate analysis. The haploid analysis of gene loci was performed by SHEsis software. Generalized multi-factor dimensionality reduction (GMDR 0.9) software was used to construct and analyze gene-gene and gene-environment interaction models. MDR (3.0.2) software was used to draw tree diagrams of gene-gene and gene-environment interactions.

Results

Comparison of SCL-90 factor scores of coal miners with the national norm in China

Compared with the national norm[29], the SCL-90 scores of coal miners showed statistically significant differences ($P<0.05$), except in the case of the interpersonal sensitivity factor ($P<0.05$). The scores of other factors of coal miners were lower than the national norm, and the scores of other factors were higher than the national norm. Table 2

Table 2. SCL-90 scores of coal miners compared with domestic norms

Variables	Coal miner($n=1675$)	Chinese norms($n=1338$)	t	P
Somatization	1.53±0.61	1.37±0.48	7.848	<0.001
Compulsive Symptoms	1.74±0.63	1.62±0.58	5.380	<0.001
Interpersonal Sensitivity	1.62±0.65	1.65±0.61	-1.294	0.196
Depression	1.58±0.65	1.50±0.59	3.496	<0.001
Anxiety	1.46±0.57	1.39±0.43	3.725	<0.001
Hostility	1.54±0.62	1.48±0.56	2.754	0.006
Fear	1.34±0.52	1.23±0.41	6.325	<0.001
Paranoia	1.48±0.60	1.43±0.57	2.324	0.020
Psychosis	1.41±0.54	1.29±0.42	6.674	<0.001
Another Factors	1.60±0.63	1.65±0.61	-2.195	0.028
SCL-90 Total Score	138.27±49.13	129.96±38.76	5.056	<0.001

Mental health status of coal miners under different MSDs conditions

The SCL-90 factor scores of coal miners with different MSDs disease conditions were compared, and the scores of all factors in the MSDs group were higher than those in the Non-MSDs group ($P<0.001$). Table 3

Table 3. Mental health status of coal mine workers under different MSDs

Variables	Non-MSDs($n=727$)	MSDs($n=948$)	t	P
Somatization	1.33±0.48	1.68±0.66	-12.179	<0.001
Compulsive Symptoms	1.56±0.52	1.88±0.67	-10.619	<0.001
Interpersonal Sensitivity	1.45±0.52	1.75±0.72	-9.603	<0.001
Depression	1.39±0.53	1.72±0.69	-10.865	<0.001
Anxiety	1.31±0.45	1.58±0.62	-10.020	<0.001
Hostility	1.35±0.50	1.68±0.67	-11.077	<0.001
Fear	1.23±0.43	1.42±0.57	-7.451	<0.001
Paranoia	1.34±0.50	1.59±0.65	-8.815	<0.001
Psychosis	1.27±0.43	1.52±0.58	-9.631	<0.001
Another Factors	1.43±0.53	1.74±0.66	-10.302	<0.001
SCL-90 Total Score	123.14±39.34	149.88±52.63	-11.462	<0.001

Hardy-Weinberg genetic balance test

The genotype distribution frequency of the *BDNF* gene and the *TPH2* gene was analyzed using the Hardy-Weinberg genetic balance test between the case group and the control group. There was no statistical significance in the distribution of the actual value and the expected value of *BDNF* (rs6265, rs10835210) gene polymorphisms and *TPH2* (rs4570625, rs4131347) gene polymorphisms in the case group and the control group ($P>0.05$). Table 4

Table 4. Genetic locus Hardy-Weinberg genetic balance test

Gene	Genotype	Case group		χ^2	<i>P</i>	Control group		χ^2	<i>P</i>
		Actual value	Expectation values			Actual value	Expectation values		
<i>BDNF</i>	rs6265								
	AA	65	71.3	2.555	0.110	50	52.9	0.545	0.460
	AG	137	124.4			130	124.2		
	GG	48	54.3			70	72.9		
	rs10835210								
	AA	27	32.8	2.489	0.115	16	20.7	2.134	0.144
	AC	127	115.5			112	102.5		
	CC	96	101.8			122	126.7		
<i>TPH-2</i>	rs4570625								
	GG	76	82.9	3.234	0.072	58	60.5	0.405	0.524
	GT	136	122.1			130	125.0		
	TT	38	44.9			62	64.5		
	rs4131347								
	CC	70	68.6	0.118	0.731	77	71.3	2.107	0.147
	CG	122	124.7			113	124.4		
	GG	58	56.6			60	54.3		

Genotypes and allele frequencies of *BDNF* and *TPH2*

Except for *TPH2* rs4131347 gene polymorphism, the genotype and allele distribution frequency of *BDNF* (rs6265, rs10835210) and *TPH2* rs4570625 gene polymorphisms showed statistical significance between the case group and the control group ($P<0.05$). The results suggested that rs6265 and rs10835210 of the *BDNF* gene and rs4570625 of the *TPH2* gene were associated with the occurrence of mental disorders. Table 5

Table 5. Distribution frequency of *BDNF*, *TPH-2* genotypes, and alleles in the case group and control group

Gene	Genotype/allele	Case group%	Control group%	χ^2	<i>P</i>
<i>BDNF</i> rs6265	AA	65±26.0	50±20.0	6.242	0.044
	AG	137±54.8	130±52.0		
	GG	48±19.2	70±28.0		
	A	267±53.4	230±46.0	5.476	0.019
	G	233±46.6	270±54.0		
<i>BDNF</i> rs10835210	AA	27±10.8	16 ±6.4	6.856	0.032
	AC	127±50.8	112±44.8		
	CC	96±38.4	122±48.8		
	A	181±36.2	144±28.8	6.240	0.013
	C	319±63.8	356±71.2		
<i>TPH-2</i> rs4570625	GG	76±30.4	58±23.2	8.313	0.016
	GT	136±54.4	130±52.0		
	TT	38±15.2	62±24.8		
	G	288±57.6	246±49.2	7.089	0.008
	T	212±42.4	254±50.8		
<i>TPH-2</i> rs4131347	CC	70±28.0	77±30.8	0.712	0.701
	CG	122±48.8	113±45.2		
	GG	58±23.2	60±24.0		
	C	262±52.4	267±53.4	0.100	0.751
	G	238±47.6	233±46.6		

Correlation analysis of *BDNF* gene haplotypes and mental disorders

Based on linkage-disequilibrium across gene loci, we determined the following: the *BDNF* gene rs6265 locus and rs10835210 coefficient $D' = 0.070$, $R^2 = 0.002$, Global chi-square= 35.690, and genotype distribution frequency >0.03 . The results suggested that the linkage imbalance between rs6265 and rs10835210 was not obvious. Four haplotypes (A-A, A-C, G-A, and G-C) were constructed using the software. The distribution of A-A haplotypes and G-A haplotypes was statistically different between the case group and the control group ($P < 0.05$), and A-A haplotypes were identified as the risk factors for mental disorders, while G-A haplotypes were protective factors for mental disorders. Figure 1, Table 6

Table 6. Analysis of the association between haplotypes of *BDNF* gene SNPs and mental disorders

Haplotype	Case group[%]	Control group[%]	χ^2	<i>P</i>	OR[95% CI]
A-A	105.82±21.2	40.82 ±8.2	33.760	<0.001	3.020[2.054~4.440]
A-C	161.18±32.2	189.18±37.8	3.444	0.064	0.782[0.602~1.014]
G-A	75.18±15.0	103.18±20.6	5.348	0.021	0.681[0.491~0.944]
G-C	157.82±31.6	166.82±33.4	0.370	0.543	0.921[0.707~1.200]

Correlation analysis of *TPH2* gene haplotypes and mental disorders

The results showed the following: The linkage-disequilibrium coefficient $D'=0.161$, $R^2=0.020$, Global chi-square= 8.084, and the genotype distribution frequency was >0.03 for *TPH2* gene rs4570625 and rs4131347. The results suggested that the linkage-disequilibrium between rs4570625 and rs4131347 was not obvious. The software constructed G-C, G-G, T-C, and T-G haplotypes. The distribution of G-C haplotypes and T-C haplotypes was statistically different between the case group and the control group ($P<0.05$), and T-C haplotypes were a risk factor for mental disorders, while G-C haplotypes were a protective factor for mental disorders. Figure 2, Table 7

Table 7. Analysis of the association between haplotypes of *TPH2* gene SNPs and mental disorders

Haplotype	Case group[%]	Control group[%]	χ^2	<i>P</i>	OR[95% CI]
G-C	110.00±22.0	137.71±27.5	4.120	0.042	0.742[0.556~0.990]
G-G	136.00±27.2	150.29±30.1	0.999	0.317	0.869[0.661~1.144]
T-C	157.00±31.4	124.29±24.9	5.292	0.021	1.384[1.049~1.825]
T-G	97.00±19.4	87.71±17.5	0.573	0.449	1.131[0.822~1.558]

GMDR constructs the gene-environment interaction model

GMDR software was used to analyze the interaction of *BDNF* gene, *TPH2* gene, and MSDs gene on psychological disorders. The cross-consistency coefficient of the interaction model between MSDs and *BDNF* gene rs6265, and *TPH2* gene rs4570625 was the highest (10/10). The accuracy of the training set was 0.66 and the accuracy of the test set was 0.62, which was statistically significant ($P=0.011$). The results showed that MSDs interacted with *BDNF* rs6265 and *TPH2* rs4570625. Table 8, Figure 3. The tree diagram showed that there was a strong positive interaction between *TPH2* gene rs4570625 and MSDs. Figure 4.

Table 8. GMDR: A gene-environment interaction model

Model	Precision		Sign test		Cross validation
	training set	test set	χ^2	P	Consistency coefficient
MSDs	0.56	0.52	6	0.377	7/10
<i>TPH-2</i> rs4570625*MSDs	0.62	0.60	10	0.001	10/10
<i>BDNF</i> rs6265* <i>TPH-2</i> rs4570625*MSDs	0.66	0.62	9	0.011	10/10

Logistic regression analysis of the gene-environment interaction

Mental disorders were taken as the dependent variable. Then, combined with the GMDR results, MSDs, MSDs *rs4570625, and MSDs *rs6265*rs4570625 were introduced into the equation for further logistic regression analysis of gene-environment interactions. The results showed that rs4570625(GG)*MSDs (OR=6.000,95%CI:1.723-20.889) rs4570625(GT)*rs6265(AA)*MSDs(OR=12.444,95%CI:3.031-51.079) rs4570625(GT)*rs6265(AG)*MSDs(OR=5.765,95%CI:1.530-21.718). Gene-environment interactions are risk factors for mental disorders. Figure 5.

Discussion

The results of this study showed that the coal miners' SCL-90 scores were higher than the national norm, and the mental health of coal miners was poor. Coal miners work in a difficult environment, their work place is far away from the city, the climatic conditions are harsh, and there is a lack of recreational facilities. Therefore, it is easy to understand that these workers have no outlet to vent work-related pressure and negative emotions, which may easily cause them to develop psychological problems over the long run [30]. At the same time, coal mine work is high-risk, and workers are obliged to bear huge risks. On the one hand, the underground work environment is dark, the air is humid, and the work is made more difficult by the harm that is cause by noise and dust. Lei et al [31] believed that the longer coal miners were exposed to dust, the lower their quality of life and the poorer their mental health. Lu et al.[32] utilized propensity score analysis to demonstrate that occupational hazards, such as asbestos dust, benzene, and noise in the work environment, adversely affect the physical and mental health of workers, causing physical and psychological harm to workers. On the other hand, accidents, such as gas poisoning, an explosion, flooding, a cave-in, gas ejection, and fire, pose threats to the safety and lives of the workers, as these events can happen at any time during their work, so the miners are subject to immense psychological pressure, which affects their mental health [33]. Although the development of coal mining technology has improved the mechanization of underground operations and greatly reduced the workload of workers, new requirements have also been put forward for the knowledge structure of underground workers. Coal miners are generally poorly educated and lack the time and energy to enhance their knowledge or improve their working skills. Therefore, they feel that they lack job security and are prone to anxiety. Han et al. [34] investigated the mental health status of 642 coal miners from six coal mining companies in six provinces in China and found that the mental health status of coal miners was poor, especially among older people, those with low incomes, and low education level.

MSDs patients scored higher on the SCL-90 than workers who did not suffer from MSDs. The reason for this may be that miners work at narrow coal faces for a long period of time, which places great physical and psychological pressure on miners, and thus, leads to physical discomfort, such as back pain and muscle pain,

as well as adverse psychological emotions. Liu Yujiao [35] believed that underground work, especially underground mining work, means that coal miners are subjected to a high labor intensity, narrow coal faces, and high physical demands. High work-loads over the long-term means that miners are likely to experience muscle strain, problems with the neck, shoulder, waist, and limbs, and other physical symptoms. Such physical discomfort can easily bring about psychological changes in the workers. If a negative mood cannot be alleviated, this will further aggravate any physical discomfort. Moreover, physical discomfort that arises as a response to psychological stress can further exacerbate the mental health problems of workers. Studies have proposed that there is a bidirectional association between MSDs and psychological factors, i.e., a feedback loop, which harms the physical and mental health of workers [36]. Cho et al. [37] investigated 2,037 subway workers and found that workers with high scores on depression, anxiety, and stress scales, especially among shift workers, showed a significant increase in the prevalence of musculoskeletal symptoms. The management of musculoskeletal symptoms should consider both ergonomic and mental health factors. The occurrence of MSDs is mainly related to physical loads, static loads, poor posture, and repetitive tasks, etc. With the deepening of research, greater attention is gradually being paid to the influence of social psychological factors on MSDs.

BDNF gene polymorphisms affect the *BDNF* transport and secretion process, thereby regulating the occurrence and development of mental diseases and changes in cognitive function. [38]. It has been found that the *BDNF* rs6265 gene polymorphism can affect synaptic transmission of NMDA receptors in the hippocampus and amygdala, increasing depressive and anxiety-related behavior [39, 40], which highlights how *BDNF* plays an important role in the development and treatment of neuropsychiatric disorders [41]. The rs4570625 polymorphism, located in the promoter region, is the most extensive polymorphic locus in studies on the association between the *TPH2* gene and psychological diseases [42]. At present, the research results of domestic and foreign scholars on the rs4570625 locus are not consistent. Gao found that, compared with individuals with the homozygous T allele at rs4570625, G allele carriers (GG or GT) had a higher incidence of depression, schizophrenia, suicide, and other diseases [43]. Similar results have been obtained in many studies [44, 14]. Some studies have also pointed out that no relationship was found between *TPH2* rs4570625 gene polymorphism and psychological disorders [45]. This study conducted a haplotype analysis of *BDNF* gene (rs6265, rs10835210) and *TPH2* gene (rs4570625, rs4131347). The findings revealed an association between the occurrence of psychological disorders and rs6265 and rs10835210 in *BDNF* gene, as well as rs4570625 in *TPH2* gene. The *BDNF* gene A-A haplotype is a risk factor for psychological disorders, and the G-A haplotype is a protective factor for psychological disorders. The T-C haplotype of the *TPH2* gene is a risk factor for psychological disorders, while the G-C haplotype is a protective factor for psychological disorders. GMDR was used to construct the gene-environment interaction model, and the results suggested that there were interactions between MSDs and *BDNF* gene rs6265 and *TPH2* gene rs4570625. A strong positive interaction was detected between *TPH2* gene rs4570625 and MSDs. Combined with the GMDR results, further logistic regression analysis of gene-environment interaction showed that the interaction between *BDNF* (rs6265), *TPH2* (rs4570625), and MSDs was a risk factor for mental disorders.

Conclusion

MSDs, the *BDNF* gene, and the *TPH2* gene were identified as influencing factors with respect to the mental health of coal miners. Gene-environment interactions have also been found to influence the mental health of

coal miners. It is suggested that employers should improve the work environment of such workers, shorten their working time, consider the mental health of workers, and ensure that psychological counseling is provided to workers with mental health problems in a timely manner, so as to improve the mental health and working ability of the workers, as well as their quality of life. Some shortcomings of this study included the following: (1) This study involved a cross-sectional survey, so it was difficult to infer any causal relationships. A cohort study will be carried out to further clarify the relationship between the MSDs, the *BDNF* gene, and the *TPH-2* gene. (2) The object of this survey was limited to only coal miners in one area, so the conclusions reached should be extrapolated with caution. In the future, the sample size will be expanded to investigate the research subjects in multiple regions. (3) The measurement indicators of mental health are relatively single, so the measurement tools should be appropriately increased to ensure the accuracy of the measurement.

Declarations

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Authors' contributions

T.J., X.L., and J.L. conceived and designed the study, T.J., X.L., and Q.X. contributed to acquisition, analysis, and interpretation of data, X.L., T.J., Q.X. and J.L. were involved in drafting the manuscript and revising it for important intellectual content. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations Ethics approval and consent to participate

The study was approved by the ethics committee of Xinjiang Medical University. Informed consent of all participate was obtained for this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no conflict of interest.

Statements

The study protocol is performed in accordance with the relevant guidelines.

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Figures

Figure 1

BDNF linkage imbalance analysis left: D' test, right: r2 test

Figure 2

		MSDs					
		0			1		
		BDNFrs6265					
		AA	AG	GG	AA	AG	GG
TPH-2rs4570625	GG	0.5	-3.0	2.5	-9.0	1.5	-3.5
	GT	3.5	-8.0	16.5	-17.0	9.5	-10.0
	TT	4.0	-3.5	11.5	-6.5	3.5	-7.5

Gene-environment interaction model Note: The dark gray grid and the light gray grid represent high-risk and low-risk combinations, respectively. The left and right columns in the grid represent the case group and control group scores, respectively.

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Figure 5

A logistic regression analysis of the impact of the gene-environment interaction on mental health