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ORIGINAL RESEARCH

# Safety Stressors and Coal Miners' Safety Performance: The Mediating Role of Resilience and Coping Styles

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**Purpose:** This study aimed to investigate the effects of three different safety stressors (safety role ambiguity, safety role conflicts, and safety interpersonal conflicts) on safety performance of coal miners under the mediating role of resilience and coping styles.

**Patients and Methods:** The study is cross-sectional. To collect data to analyze the hypothesized relationships in the present study, a total of 450 questionnaires were distributed to coal miners in Shannxi Province of China. Regression analysis was employed as the main statistical technique in analyzing the data using SPSS 22.0 and Process 4.1.

**Results:** The results of regression analysis indicate that the three kind of safety stressors have a negative predictive effect on coal miners' safety performance. Resilience and coping styles both were the mediating variables between the safety stressors (safety role ambiguity, safety role conflicts, and safety interpersonal conflicts) and coal miners' safety performance, and resilience and coping styles play a chain mediating role between the safety stressors (safety role ambiguity, safety role conflicts, and safety interpersonal conflicts) and safety performance of coal miners.

**Conclusion:** This study further explores the mechanism between safety stressors and safety performance, providing theoretical guidance for improving the safety performance of coal mines. It emphasizes the importance of coal miner's resilience intervention, positive coping styles promotion, and negative coping styles prevention in coal mine safety production.

**Keywords:** safety performance, resilience, safety stressors, coping styles

## Introduction

In China, underground coal mining is considered one of the most dangerous jobs.[1] Even with the continuous improvement of mining safety production in China in 2021, a total of 356 accidents occurred in coal mines nationwide, resulting in 503 deaths and a mortality rate of 0.044 per million tons.[2] However, from 2005 to 2014, the average annual mortality rate in the United States was as low as 0.0208 per million tons.[3] There is still a significant gap between China and developed countries in terms of the safety of coal mine production. We need to ensure workplace safety to reduce the personal damage and property loss caused by the coal mine accident.[4] Safety performance has always been a hot topic of research because it can improve workplace safety.[5–9]

Environmental pollution in soil,[10] food,[11–34] water resources,[35] air,[36–38] is increasing with the industrialization of countries[39–54] and may reduce workplace safety. These pollutants including mycotoxins,[47,55–59] radioactive elements,[60] microbial,[61–63] heavy metals,[64–72] hormones,[73] pesticides,[74–76] antibiotics[77,78] caused various diseases.[79,80]

The definition of safety performance has always lacked consistency in the academic field.[5] Some scholars believe that safety performance may refers to an organizational metric for safety outcomes, such as accident rate, injury rate, mortality rate, etc.[81] However, this definition cannot provide advance warning for safety accidents, so scholars generally

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believe that safety performance may refers to a metric for safety-related behaviors of individuals.[82] This definition provides researchers with measurable indicators,[4] and the more widely used method is to evaluate employees' safety compliance (SC) and safety participation (SP), which is a more scientific way to measure safety performance.[83]

SC refers to the core safety activities that individuals must undertake to maintain workplace safety, and SP refers to behaviors such as participating in voluntary safety activities or attending safety meetings.[84] This article will adopt this definition. It is worth mentioning that safety performance belongs to a separate field of work performance, and the difference between the two is about their task, contextual or adaptive.[82,85]

At present, research on safety performance has made some progress. Scholars usually formulate relevant safety management policies by exploring factors that may have a predictive effect on safety performance.[86] Safety stressors is occupational stressors in the context of safety. Scholars generally believe that safety stressors will have a negative effect on the safety performance of workers[5,86–88] However, most of the previous research focused on pipeline installers, construction workers, and oil workers,[5,86,88] but coal miners have not been surveyed. Therefore, to better the safety performance of coal miners, we should research the mediating mechanism of safety stressors and safety performance. And some scholars have confirmed that evaluating subjective support, psychological capital, and safety-specific trust, as well as ego depletion and self-efficacy, moderating or mediating effect on the relationship between safety stressors and safety performance.[5,86] However, the two essential abilities or psychological resources that individuals use to cope with stress, namely resilience and coping styles, have not been explored.[89–91] In general, the impact mechanism between safety stressors and safety performance needs further exploration for propose safety management policies to improve safety production in coal mine.

# Hypotheses Development

## The Relationship Between Safety Stressors and Safety Performance

There are various types of safety stressors,[86] and the impact of stressors on performance varies with the type of stressors and the performance dimensions being examined.[92] This article mainly focuses on three types of safety stressors that often exist in high-risk industries: safety role ambiguity (SRA), safety role conflicts (SRC), and safety interpersonal conflicts (ISC). SRA refers to situations where available information and resources related to safety roles are unclear or insufficient. SRC reflects inconsistencies between safety expectations and evaluation criteria. ISC refers to the occurrence of safety disputes among organizational members.[5]

Sampson et al found that SRA, SRC and ISC are negatively correlated with SC. However, only SRA and SRC are significantly negative correlated with SC.[5] Wang et al argue that all three types of safety stressors (SRA, SCR, and ISC) have a negative impact on the SP of construction workers, while only SRA has a significant negative effect on SC.[86] Ye et al found that three types of safety stressors (SRA, SCR, and ISC) all have a negative impact on the safety performance (SC and SP) of construction workers.[88] However, due to different measurement scale and respondent, there are specific differences in the relationship between the three types of safety stressors and the two sub-dimensions of safety performance.[88] Therefore, this article takes coal miners as the survey object and verifies the impact between the three types of safety stressors and the two sub-dimensions of safety performance again.

According to action theory,[93] if working conditions disrupt information processing and require mental labor, it can trigger adverse reactions. For example, if an employee does not know what they should do, this may lead to a lack of guidance on when to perform tasks, which may result in a decrease in job performance.[94] Besides, Abbas and Raja found that hindrance job stressors had negative effects on job performance.[95] Therefore, according to the definition of SRA, SRC and ISC, they are highly likely to generate information that disrupts work, and they are all hindrance job stressors that hinder workers' personal growth and goal attainment.[96,97] We propose the hypothesis:

H1: Safety role ambiguity (H1a), safety role conflict (H1b), and interpersonal safety conflict (H1c) have negative effects on workers' safety compliance.

H2: Safety role ambiguity (H2a), safety role conflict (H2b), and interpersonal safety conflict (H2c) have negative effects on workers' safety participation.

## The Mediating Role of Resilience

With the rise of positive psychology, the resilience closely related to positive psychology is also receiving increasing attention.[91,98,99] Resilience(PR), also known as psychological resilience, refers to the positive psychological state that an individual experiences under adversity, and stress stimuli are a vital psychological resource.[5,81,100] SRA, SRC, and ISC, as hindrance stressors,[96] require more psychological resources to cope with and result in a loss of individual resources.[91,101] Previous studies have found that hindrance stressors (role conflicts, task conflicts, etc.) have a negative impact on the resilience of miners. Therefore, we hypothesize:

H3: Safety role ambiguity (H3a), safety role conflict (H3b), and interpersonal safety conflict (H3c) have negative effects on resilience.

In addition, Studies have found that resilience can help coal miners cope with the high-pressure environment of coal mine production and reduce their unsafe behaviors.[102] Resilience has a significant positive impact on the SC and SP of railway constructors.[103] Aviation safety officers have a high degree of psychological resilience, which helps them fulfill their safety responsibilities, improve their safety behavior, and ultimately achieve safety performance improvement.[104] Therefore, we hypothesize:

H4: Resilience has positive effects on safety compliance (H4a) and safety participation (H4b).

In summary, SRA, SRC, and ISC as hindrance stressors can consume the resilience of miners[102] and resilience positively effect on safety performance (SC and SP), we hypothesize:

H5: Resilience mediates the relationship between safety role ambiguity (h5a), safety role conflict (H5b), interpersonal safety conflict (H5c), and safety compliance.

H6: Resilience mediates the relationship between safety role ambiguity (H6a), safety role conflict (H6b), safety interpersonal conflict (H6c), and safety participation.

## The Mediating Role of Coping Styles

Coping styles refer to the constantly changing cognitive and behavioral efforts made to manage external and/or internal demands that are seen as exceeding or depleting resources, which are influenced by characteristics such as personality, abilities, and social skills. It often acts between stress and outcomes, divided into positive coping styles (PCS) and negative coping styles (NCS).[105] PCS refer to individuals taking problem-solving as their orientation, actively seeking internal and external resources, and actively constructing problem-solving strategies. NCS refer to the tendency of individuals to adopt avoidance, denial, fantasy, and other methods to cope with problems.[106] The theory of pressure imbalance compensation[107] suggests that long-term exposure to stress can lead to internal system imbalances, and individuals will adopt different coping styles to compensate for these imbalances. The direction and extent of the impact depend on their own choices.[108] Scholars have found that the greater stress staff faced, they tend to choose negative coping styles rather than positive coping styles.[107] Therefore, we hypothesize:

H7: Safety role ambiguity (H7a), safety role conflict (H7b), and interpersonal safety conflict (H3c) have negative effects on positive coping styles.

H8: Safety role ambiguity (H8a), safety role conflict (H8b), and interpersonal safety conflict (H3c) have positive effects on negative coping styles.

In addition, research has confirmed that positive coping styles can significantly positively predict work performance,[109] The coping styles of construction workers have a significant impact on their unsafe behavior.[110] Positive coping styles can enhance positive emotions and lead to positive outcomes.[111,112] Contrarily, individuals who use negative coping styles tend to doubt their abilities, leading to negative outcomes.[113] This article proposes the hypothesis:

H9: Positive coping styles have a positive effect on Safety Compliance (H9a) and Safety Participation (H9b).

H10: Negative coping styles have a negative effect on safety Safety Compliance (H10a) and Safety Participation (H10b).

In summary, we hypothesize:

H11: Coping styles (PCS and NCS) mediate the relationship between safety role ambiguity (H11a), safety role conflict (H11b), safety interpersonal conflict (H11c), and safety compliance.

H12: Coping styles (PCS and NCS) mediate the relationship between safety role ambiguity (H12a), safety role conflict (H12b), safety interpersonal conflict (H12c), and safety participation.

## The Multiple-Step Mediating Effects Through Resilience and Coping Styles

Resilience, as an individual's "buffer" in the face of stress, mainly depends on personal and social factors.[114] Coping styles are usually recognized as the cognitive and behavioral methods that individuals take to alleviate or eliminate the situation or event when confronted with a stressful situation or stressful event.[115] Thompson et al found that resilience was related to positive coping styles: individuals with low resilience might adopt negative coping styles in the face of stress, while those with high levels of resilience were inclined to seek positive coping styles such as social support and problem-solving.[116] This view has also been confirmed in the study by Xie et al.[117] Thus, we hypothesize:

H13: Resilience has positive effects on positive coping styles (H13a) and negative effects on negative coping styles (H13b).

As mentioned above, three types of safety stressors (SRA, SRC, and ISC) may have a negative effect on the resilience of workers. Resilience promotes positive coping styles, weakens negative coping styles, and then effects on safety performance. Therefore, SRA, SRC, and ISC have an effect on safety performance through the multi-step mediating effect of resilience and coping styles. In other words, resilience serves as a "buffer" for safety stress, which, to some extent, prevents workers from choosing negative coping styles and encourages them to choose positive coping styles, thereby effecting safety performance.

H14: Safety role ambiguity (H14a), safety role conflict (H14b), and interpersonal safety conflict (H14c) effect coal miners' safety compliance through the multiple-step mediating effect of resilience and coping styles (PCS and NCS).

H15: Safety role ambiguity (H15a), safety role conflict (H15b), and interpersonal safety conflict (H15c) effect coal miners' safety participation through the multiple-step mediating effect of resilience and coping styles (PCS and NCS).

The conceptual framework and hypotheses stated above are shown in Figure 1.

# Methods

## Participants and Data Collection Procedures

In this study, a questionnaire survey was conducted to collect hypothesis-testing data. Before the formal survey, we sent a preliminary questionnaire to ten workers in a coal mine in Yulin City, Shaanxi Province. We conducted a prediction test to modify potentially confused items. According to the feedback of ten staff, we further revised some items to simplify the language and facilitate understanding. The formal investigation was conducted in three coal mining enterprises in Shaanxi Province of China from February 2022 to April 2022. The survey was conducted on-site and online at the same time. A total of 450 questionnaires were sent out. 241 questionnaires (53.56%) were distributed on-site, and 209 questionnaires (46.44%) were distributed online. Participants were first-line coal miners. The questionnaires with no answers exceeding 5%[118] and arbitrary answers (eg, there are obvious repetition patterns in the answers) are excluded, and the final valid samples are 364 (the effective response rate is 80.89%). If the effective sample size reaches five times or more of the number of items, it can be tested, the obtained data can be verified.[119]

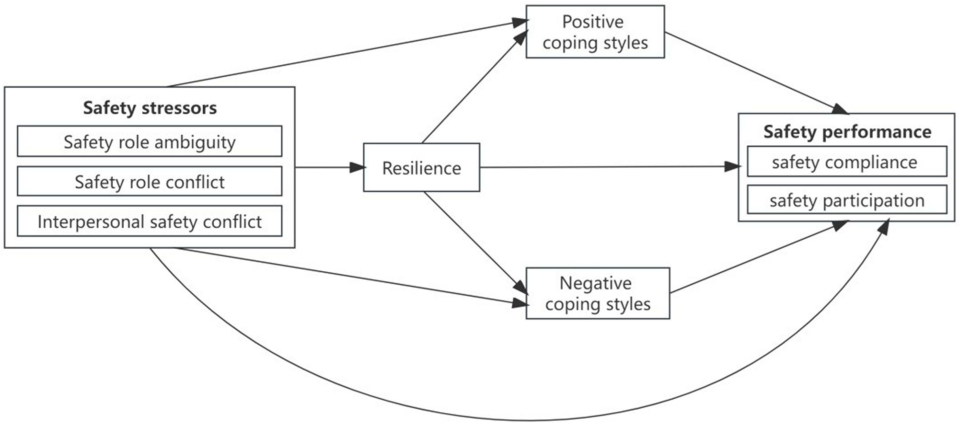


**Figure 1** Conceptual framework and hypothesis.

According to the demographic results of the respondents (Table 1), the respondents were male, accounting for 100% (n=364). The age of all respondents was mainly distributed between 31 and 40 years old, accounting for 59.34% (n=216), more than half of the total number of respondents. 78.29% (n=285) of the respondents had worked in the coal industry for more than five years, and 79.67% (n=290) of them were married. In terms of educational background, with the development of wisdom mine in recent years, the degree of digitization of coal mine production in China has improved, and the education degree of coal miners has been greatly improved.[120] 73.93% (n=269) of the respondents have Junior college degree or above.

## Measures

In order to ensure the scientific of this study, the questions in the questionnaire are developed using the validated scale that has been used in previous studies. These scales were translated into Chinese using standard translations prior to use. The survey content includes safety stressors, resilience, coping styles, and safety performance.

**Table 1** Demographic Characteristics of the Respondents (N=364)

| Characteristics | Items | Frequency | Percentage (%) |
|---|---|---|---|
| Gender | Male | 364 | 100.00 |
| | Female | 0 | 0.00 |
| Age | Below 30 | 84 | 23.08 |
| | 31–40 | 216 | 59.34 |
| | 41–50 | 48 | 13.19 |
| | More than 51 | 16 | 4.40 |
| Marital status | Unmarried | 74 | 20.33 |
| | Married | 290 | 79.67 |
| Work experience | Below 5 years | 27 | 7.42 |
| | 5–10 years | 68 | 18.68 |
| | 11–20 years | 115 | 31.59 |
| | 21–30 years | 102 | 28.02 |
| | More than 30 years | 52 | 14.29 |
| Educational Background | Secondary school or below | 33 | 9.07 |
| | High school | 62 | 17.03 |
| | Junior college | 196 | 53.85 |
| | Undergraduate and above | 73 | 20.05 |

**Note**: Item high school including technical secondary school and technical school.

### Safety Stressors

According to Sampson et al[5] and Fu et al.[121] This paper mainly focuses on three kinds of safety stressors and uses 18 items to measure them, namely safety role ambiguity (SRA, 5 items), safety role conflict (SRC, 9 items), and interpersonal safety conflict (ISC, 4 items). The sample items of the three sub-scales include "My work has no clear and planned security goals", "In order to perform tasks safely, I must ignore the rules or policies", and "I argue with others in work on safety issues". The scale of SRA and SRC is measured according to the consistency of 1 (strongly disagree) to 5 (strongly agree), while the scale of ISC is measured according to the occurrence frequency of 1 (never) to 5 (extremely frequent).

### Resilience

Resilience measurements using the revised Connor-Davidson Resilience Scale (CD-RISC),[122] the scale measures resilience as an individual trait and is widely used in resilience research. Scholars Yu Xiaonan and Zhang Jianxin revised the scale in Chinese and measured it in three dimensions: tenacity, strength, and optimism. There are 25 items on the scale, including 13 items to measure tenacity, such as "when things do not seem to have much hope, I will not give up easily", 8 items to measure strength, such as "coping with stress makes me feel powerful", 4 items to measure optimism, such as "whatever happens I can deal with", resilience scale items from 1 (very disagree) to 5 (very agree).

### Coping Styles

The Simple Coping Style Scale (SCSQ), prepared by Xie[123] was adopted. This scale has a total of 20 items encompassing two dimensions: positive coping style (12 items), such as "Try to see the bright side of things", and negative coping style (8 items), such as "Accept reality because there is no other way". According to a 0–5 score range, representing "never" to "extremely frequent".

### Safety Performance

The safety performance measurement scale used in this study was developed by Griffin,[84] including 4 items measuring safety compliance (SC) and 3 items measuring safety participation (SP). Measurement items include "I use the correct security program at work", "when my colleagues work in dangerous or harmful conditions, I help them", and so on. All items scored from 1 (very disagree) to 5 (very agree).

## Data Analysis Procedures

First, reliability analysis and validity analysis were employed to evaluate the quality of the measurement model for ensure that the measurement scale can accurately measure the variables. Reliability was assessed by Cronbach's alpha value of variables, the result were produced by SPSS version 22.0. Validity analysis was assessed by confirmatory factor analysis (CFA) which produced by AMOS version 22. Second, SPSS version 22.0 was used for descriptive statistical analysis of the questionnaire data, through which the mean, standard deviation (SD), and correlation coefficients of the variables were obtained. Then, SPSS 22.0 and SPSS PROCESS 4.1 were used to build a multiple Regression Model to test the research hypotheses. A three-step method was applied to examine the hypothesis,[124] The first step examines the effect of independent variables on dependent variables (H1 and H2); the second step, the influence of independent variables on mediators and the effect of mediators on dependent variables were examined (testing H3, H4, H7, H8, H9, H10, and H13). The last step was used to develop a hierarchical multiple regression (use SPSS PROCESS Macro Model 81) to examine the mediation effects (testing H5, H6, H11, H12, H14, and H15).

According to other literature related to safety behavior, four demographics (Participant age, education, marriage status, and work experience) were collected and included during analysis to control for confounding effects.[125,126]

# Analyses and Results

## Assessment of Measurement Reliability and Validity

The reliability which tested by Cronbach's alpha value was ranging from 0.806 to 0.951, reaching the accepted threshold value of 0.7.[127]

Convergent validity was assessed by the indices of standard factor loading (SFL), construct reliability (CR), and average variance extracted (AVE) recording to confirmatory factor analysis (CFA). The result of first CFA led to deleting 13 items of resilience to prevent negative variance. The final result of SFL, CR and AVE (as well as Cronbach's alpha) are presented in Table 2. The SFL of all the variables were greater than the 0.50 threshold and the construct reliabilities of the variables were also greater than the 0.70 and were statistically significant at a 5% confidence level. For the AVE, all of the variables had AVE ranging from 0.602 to 0.837 and were above the 0.50 threshold showing good convergent validity. In addition to checking whether the variables were distinct from each other, the discriminant validity for all the variables was checked and the results are presented along the diagonal line of the inter-factor correlation analysis (See the Bold numbers of Table 3). The discriminant validity results show that the variables are distinct from each other since they are greater than the inter-factor correlation values. All measurements satisfactorily fit the data.

## Descriptive Analyses and Person

The mean and standard deviation (SD) of variables and the correlation coefficients among variables are shown in Table 3. SRA, SRC, and ISC were negatively related to SC and SP. SRA, SRC, and ISC were negatively related to PR. SRA, SRC, and ISC were negatively related to PCS and positively related to NCS. PR was positively related to PCS and negatively related to NCS. PR was positively related to SC and SP. NCS are negatively related to SC and SP. PCS are positively related to SC and SP.

**Table 2** Results of Reliability and Validity Testing

| Variables | Indicators | Cronbach's Alpha | *CR* | SFL |
|---|---|---|---|---|
| SRA | SRA1 | 0.895 | 0.895 | 0.793 |
| | SRA2 | | | 0.771 |
| | SRA3 | | | 0.782 |
| | SRA4 | | | 0.817 |
| | SRA5 | | | 0.804 |
| SRC | SRC1 | 0.934 | 0.934 | 0.837 |
| | SRC2 | | | 0.761 |
| | SRC3 | | | 0.785 |
| | SRC4 | | | 0.76 |
| | SRC5 | | | 0.763 |
| | SRC6 | | | 0.784 |
| | SRC7 | | | 0.759 |
| | SRC8 | | | 0.803 |
| | SRC9 | | | 0.792 |
| ISC | ISC1 | 0.918 | 0.918 | 0.854 |
| | ISC2 | | | 0.86 |
| | ISC3 | | | 0.844 |
| | ISC4 | | | 0.873 |

(*Continued*)

**Table 2** (Continued).

| Variables | Indicators | Cronbach's Alpha | *CR* | SFL |
|---|---|---|---|---|
| PR | PR1 | 0.936 | 0.937 | 0.739 |
| | PR2 | | | 0.759 |
| | PR3 | | | 0.761 |
| | PR4 | | | 0.728 |
| | PR5 | | | 0.737 |
| | PR6 | | | 0.714 |
| | PR7 | | | 0.602 |
| | PR8 | | | 0.614 |
| | PR9 | | | 0.777 |
| | PR10 | | | 0.745 |
| | PR11 | | | 0.753 |
| | PR12 | | | 0.772 |
| | PR13 | | | 0.764 |
| PCS | PCS1 | 0.937 | 0.911 | 0.785 |
| | PCS2 | | | 0.776 |
| | PCS3 | | | 0.743 |
| | PCS4 | | | 0.754 |
| | PCS5 | | | 0.727 |
| | PCS6 | | | 0.746 |
| | PCS7 | | | 0.715 |
| | PCS8 | | | 0.744 |
| NCS | NCS1 | 0.919 | 0.919 | 0.823 |
| | NCS2 | | | 0.766 |
| | NCS3 | | | 0.769 |
| | NCS4 | | | 0.726 |
| | NCS5 | | | 0.774 |
| | NCS6 | | | 0.742 |
| | NCS7 | | | 0.755 |
| | NCS8 | | | 0.772 |
| SC | SC1 | 0.806 | 0.77 | 0.729 |
| | SC2 | | | 0.694 |
| | SC3 | | | 0.754 |

(*Continued*)

**Table 2** (Continued).

| Variables | Indicators | Cronbach's Alpha | *CR* | SFL |
|---|---|---|---|---|
| SP | SP1 | 0.844 | 0.838 | 0.633 |
| | SP2 | | | 0.811 |
| | SP3 | | | 0.771 |
| | SP4 | | | 0.78 |

**Table 3** Means, SD, and Correlation Coefficients Among Variables

| Variables | M | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. SRA | 2.7505 | 1.07441 | **0.794** | | | | | | | |
| 2. SRC | 2.823 | 1.04459 | 0.669** | **0.783** | | | | | | |
| 3. ISC | 2.7802 | 1.2169 | 0.619** | 0.654** | **0.858** | | | | | |
| 4. PCS | 3.4744 | 0.93437 | −0.318** | −0.344** | −0.440** | **0.749** | | | | |
| 5. NPS | 2.6648 | 0.99259 | 0.378** | 0.450** | 0.460** | −0.420** | **0.766** | | | |
| 6. PR | 3.506 | 0.81496 | −0.278** | −0.296** | −0.334** | 0.473** | −0.278** | **0.73** | | |
| 7. SC | 3.7095 | 0.86338 | −0.521** | −0.489** | −0.541** | 0.585** | −0.470** | 0.656** | **0.726** | |
| 8. SP | 3.3553 | 1.11593 | −0.454** | −0.504** | −0.514** | 0.517** | −0.536** | 0.433** | 0.656** | **0.752** |

**Notes**: **p < 0.01; Diagonal bold font indicates the square root of AVE.

## Testing of Hypotheses

First, the direct effects of the independent variables on the dependent variables were examined. The results are shown in the Table 4. SRA, SRC, and ISC negatively influenced SC (as model 1 to 3), which supported H1. SRA, SRC, and ISC had negative effects on SP, thus supporting H2 (as model 4 to 6). All the independent variables were found to have significant effects on the dependent variables.

Second, the direct effects of the independent variables on the mediators and the effect of the mediators on the dependent variables were examined. The results are shown in Table 4. SRA, SRC, and ISC negatively effect on PR (model 7 to 9), supporting H3; PR positively effect SC and SP (model 10 and 11), supporting H4; SRA, SRC, and ISC negatively effect on PCS (model 12 to 14) and positively effect on NCS (model 15 to 17), supporting H7, H8; PCS positively effect on SC and SP (model 18 and 20), NCS negatively effect on SC and SP (model 19, 21), supporting H9 and H10. PR also positively effect on PCS (model 22) and negatively effect on NCS (model 23), supporting H13. All hypothesis results are significant.

Last, we used the SPSS PROCESS Macro Model 81 for mediation effect analysis. Following the suggestion of Cheung and Lau,[128] we used the bias-corrected (BC) bootstrap method to define the confidence intervals (CI) for examining the significance of the indirect effects. The bootstrap sample size and the confidence intervals were set as 1000 and 95%, respectively. The results are shown in Figures 2–7. Table 5 shows the direct effects, indirect effects, and total effects of the hypothesized mediation model. We found that safety role ambiguity, safety role conflict, and Interpersonal safety conflict had significant indirect effects on safety compliance and safety participation through resilience (supporting H5 and H6); Safety role ambiguity, safety role conflict, and Interpersonal safety conflict had significant indirect effects on safety compliance and safety participate through coping styles (PCS and NCS) (supporting H11 and H12); Additionally, H13 was supported since the indirect effect of SRA, SRC, and ISC on SC,SP through resilience and PCS,NCS were significant.

**Table 4** Results of the Regression Analysis

| **Control variables** | **SC** | | | **SP** | | | **PR** | | | **SC** | **SP** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** | **Model 6** | **Model 7** | **Model 8** | **Model 9** | **Model 10** | **Model 11** |
| Age | 0.89 | 0.13 | 0.051 | 0.22 | 0.136 | 0.181 | 0.039 | −0.001 | 0.021 | 0.021 | 0.119 |
| Edu | −0.87 | −0.091 | −0.059 | −0.019 | −0.031 | 0.013 | −0.281*** | −0.287*** | −0.267*** | −0.267*** | 0.193*** |
| Exp | −0.36 | −0.035 | −0.053 | −0.005 | −0.002 | −0.025 | −0.056 | −0.054 | −0.065 | −0.065 | 0.023 |
| Mar | 0.57 | 0.104 | 0.131 | −0.014 | −0.033 | 0.07 | 0.339 | 0.148 | −0.059 | −0.059 | 0.109 |
| Independent Variables | | | | | | | | | | | |
| SRA | −0.43*** | | | −0.497*** | | | −0.235*** | | | | |
| SRC | | −0.409*** | | | −0.546*** | | | −0.252*** | | | |
| ISC | | | −0.388*** | | | −0.481*** | | | −0.224*** | | |
| PCS | | | | | | | | | | | |
| NCS | | | | | | | | | | | |
| PR | | | | | | | | | | 0.736*** | 0.645*** |
| R-sq | 0.289 | 0.249 | 0.305 | 0.227 | 0.263 | 0.269 | 0.157 | 0.178 | 0.182 | 0.182 | 0.211 |
| F | 2.135 | 1.214 | 1.617 | 2.412* | 1.1 | 1.770 | 9.81*** | 9.889*** | 9.06*** | 9.06*** | 2.707* |
| **Dependent variable** | **PCS** | | | **NCS** | | | **SC** | | **SP** | **PCS** | **NCS** |
| **Control variables** | **Model 12** | **Model 13** | **Model 14** | **Model 15** | **Model 16** | **Model 17** | **Model 18** | **Model 19** | **Model 20** | **Model 21** | **Model 22** | **Model 23** |
| Age | 0.147 | 0.095 | 0.131 | −0.007 | 0.05 | 0.015 | −0.049 | 0.023 | 0.061 | 0.153 | 0.088 | 0.065 |
| Edu | −0.083 | −0.09 | −0.065 | −0.022 | −0.009 | −0.043 | −0.018 | −0.071 | 0.06 | −0.007 | 0.092 | −0.154** |


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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Exp | 0.035 | 0.036 | 0.022 | −0.025 | −0.028 | −0.01 | −0.061 | −0.053 | −0.034 | −0.026 | 0.063 | −0.04 |
| Mar | −0.062 | −0.071 | −0.01 | −0.096 | −0.074 | −0.155 | 0.137 | 0.67 | 0.077 | −0.024 | 0.023 | −0.178 |
| Independent variable | | | | | | | | | | | | |
| SRA | −0.303*** | | | 0.350*** | | | | | | | | |
| SRC | | −0.320*** | | | 0.425*** | | | | | | | |
| ISC | | | −0.348*** | | | 0.375*** | | | | | | |
| PCS | | | | | | | 0.546*** | | 0.619*** | | | |
| NCS | | | | | | | | −0.412*** | | −0.608*** | | |
| PR | | | | | | | | | | | 0.571*** | −0.387*** |
| R-sq | 0.128 | 0.138 | 2.313 | 0.146 | 0.205 | 0.217 | 0.353 | 0.231 | 0.296 | 0.272 | 0.241 | 0.101 |
| F | 2.821* | 2.017 | 0.214 | 0.232 | 0.242 | 0.586 | 191.287*** | 103.669*** | 147.601*** | 130.62*** | 107.999*** | 37.193*** |

**Notes**: *p < 0.05. ***p < 0.001.



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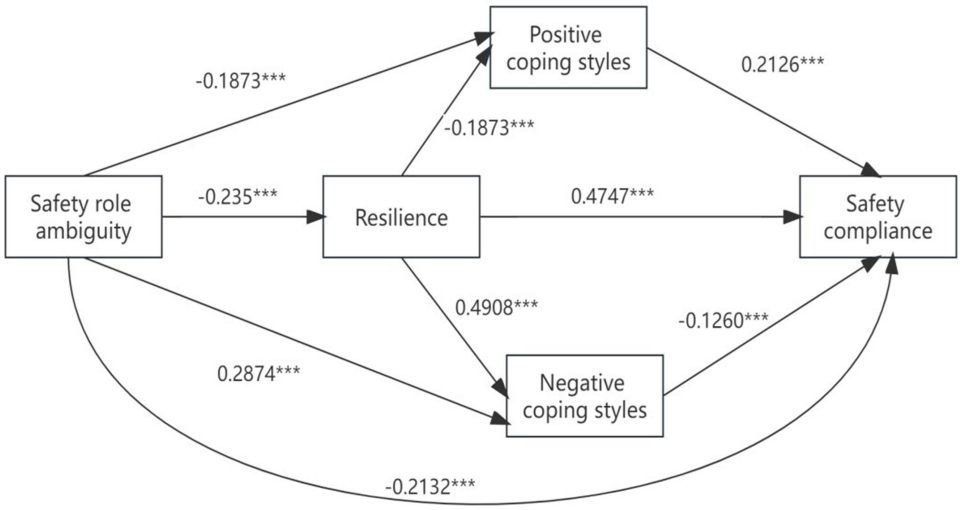


**Figure 2** Mediating roles of resilience and coping styles affect between SRA and SC. ***P < 0.001.

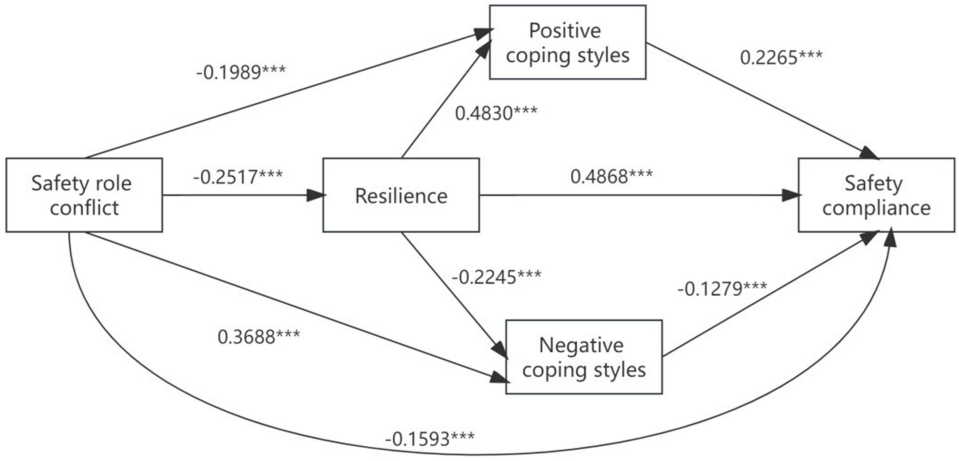


**Figure 3** Mediating roles of resilience and coping styles affect between SRC and SC. ***P < 0.001.

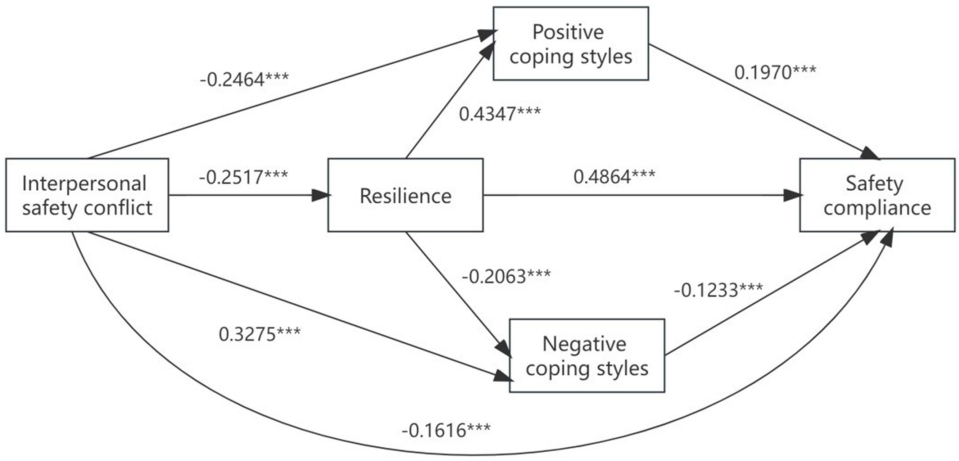


**Figure 4** Mediating roles of resilience and coping styles affect between ISC and SC. ***P < 0.001.

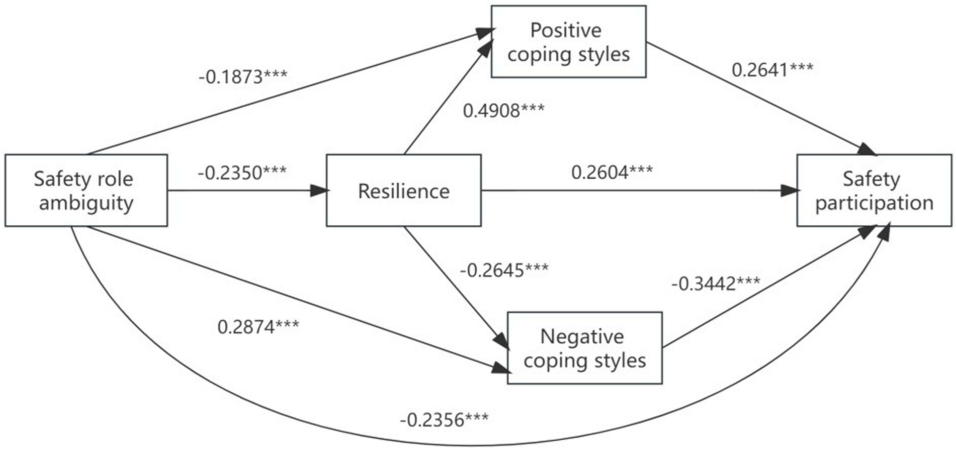


**Figure 5** Mediating roles of resilience and coping styles affect between SRA and SP. ***P < 0.001.

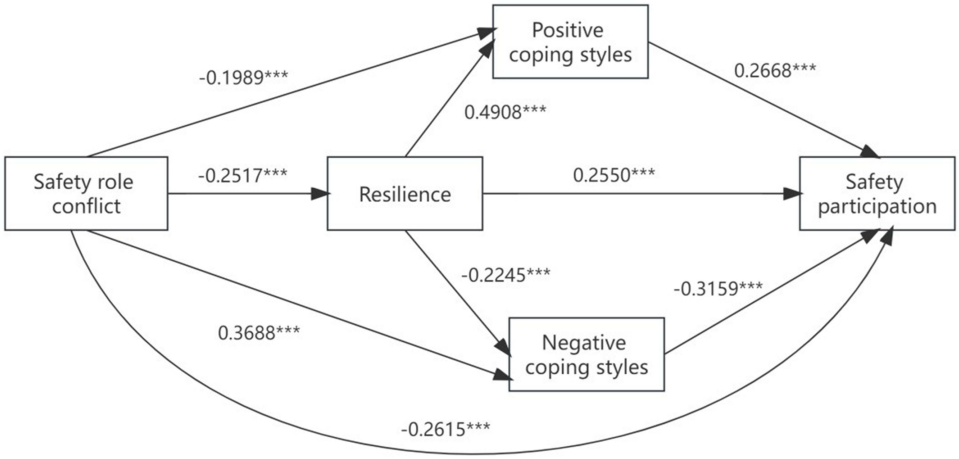


**Figure 6** Mediating roles of resilience and coping styles affect between SRC and SP. ***P < 0.001.

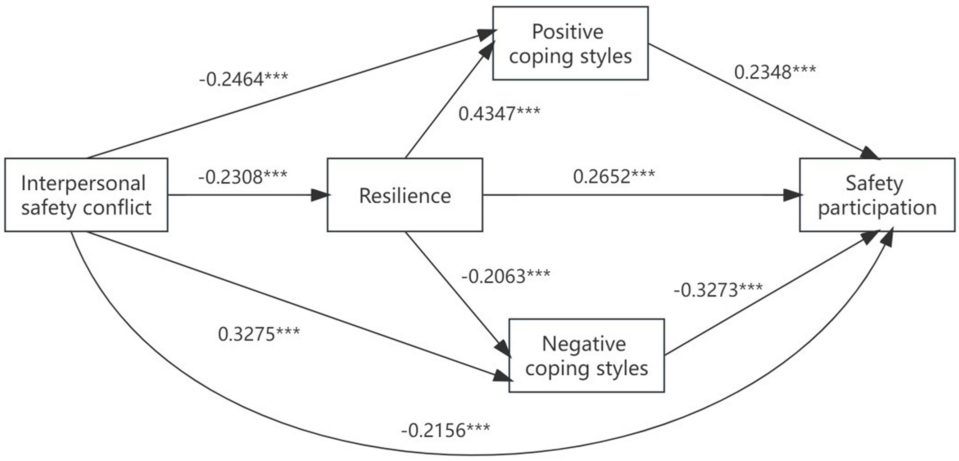


**Figure 7** Mediating roles of resilience and coping styles affect between ISC and SP. ***P < 0.001.

**Table 5** Total, Direct, and Indirect Effects of Safety Stressors on Safety Performance

| 1, SAR -> SC | | | | | |
|---|---|---|---|---|---|
| **Effects** | **Paths** | **Effect** | **Bootstrap SE** | **Bootstrap 95% CI** | **Effect Proportion** |
| Total effect | SRA->SC | −0.4331 | 0.0364 | −0.5048 to −0.3615 | 100.00% |
| Direct effect | SRA->SC | −0.2132 | 0.0293 | −0.2708 to −0.1557 | 49.23% |
| Indirect effects | SRA->PR->SC | −0.1116 | 0.0248 | −0.1642 to −0.0662 | 25.77% |
| | SRA->PCS->SC | −0.0398 | 0.0138 | −0.0706 to −0.0169 | 9.19% |
| | SRA->NPS->SC | −0.0362 | 0.0121 | −0.0625 to −0.0155 | 8.36% |
| | SRA->PR->PCS->SC | −0.0245 | 0.0075 | −0.0413 to −0.0119 | 5.66% |
| | SRA->PR->NPS->SC | −0.0078 | 0.0034 | −0.0156 to −0.0024 | 1.80% |
| **2, SRC -> SC** | | | | | |
| Total effect | SRC->SC | −0.4088 | 0.0381 | −0.4837 to −0.3338 | 100.00% |
| Direct effect | SRC->SC | −0.1593 | 0.032 | −0.2221 to −0.0965 | 38.97% |
| Indirect effects | SRC->PR->SC | −0.1225 | 0.027 | −0.1795 to −0.0742 | 29.97% |
| | SRC->PCS->SC | −0.0451 | 0.0143 | −0.0772 to −0.0204 | 11.03% |
| | SRC->NPS->SC | −0.0472 | 0.0144 | −0.0771 to −0.0206 | 11.55% |
| | SRC->PR->PCS->SC | −0.0275 | 0.0084 | −0.0465 to −0.0136 | 6.73% |
| | SRC->PR->NPS->SC | −0.0072 | 0.0036 | −0.0157 to −0.0019 | 1.76% |
| **3, ISC -> SC** | | | | | |
| Total effect | ISC->SC | −0.3884 | 0.0313 | −0.4502 to −0.3267 | 100.00% |
| Direct effect | ISC->SC | −0.1616 | 0.0281 | −0.2168 to −0.1064 | 43.25% |
| Indirect effects | ISC->PR->SC | −0.1123 | 0.0236 | −0.1619 to −0.0699 | 26.97% |
| | ISC->PCS->SC | −0.0485 | 0.0141 | −0.0786 to −0.0232 | 12.33% |
| | ISC->NPS->SC | −0.0404 | 0.0126 | −0.0668 to −0.0166 | 11.40% |
| | ISC->PR->PCS->SC | −0.0198 | 0.0066 | −0.0344 to −0.0089 | 4.75% |
| | ISC->PR->NPS->SC | −0.0059 | 0.0029 | −0.0126 to −0.0014 | 1.30% |
| **4, SAR -> SP** | | | | | |
| Total effect | ISC->SC | −0.497 | 0.0491 | −0.5936 to −0.1459 | 100.00% |
| Direct effect | ISC->SC | −0.2356 | 0.0456 | −0.3253 to −0.1459 | 47.40% |
| Indirect effects | ISC->PR->SC | −0.0612 | 0.0205 | −0.1078 to −0.0272 | 12.31% |
| | ISC->PCS->SC | −0.0495 | 0.0191 | −0.0924 to −0.0183 | 9.96% |
| | ISC->NPS->SC | −0.0989 | 0.0237 | −0.1490 to −0.0564 | 19.90% |
| | ISC->PR->PCS->SC | −0.0305 | 0.0105 | −0.0544 to −0.0130 | 6.14% |
| | ISC->PR->NPS->SC | −0.0214 | 0.008 | −0.0393 to −0.0084 | 4.31% |

(*Continued*)

**Table 5** (Continued).

| 1, SAR -> SC | | | | | |
|---|---|---|---|---|---|
| **Effects** | **Paths** | **Effect** | **Bootstrap SE** | **Bootstrap 95% CI** | **Effect Proportion** |
| **5, SRC -> SP** | | | | | |
| Total effect | ISC->SC | −0.5455 | 0.0488 | −0.6415 to −0.4496 | 100.00% |
| Direct effect | ISC->SC | −0.2614 | 0.0479 | −0.3556 to −0.1673 | 47.92% |
| Indirect effects | ISC->PR->SC | −0.0642 | 0.021 | −0.1115 to −0.0284 | 11.77% |
| | ISC->PCS->SC | −0.0531 | 0.02 | −0.0982 to −0.0199 | 9.73% |
| | ISC->NPS->SC | −0.1165 | 0.0272 | −0.1731 to −0.0673 | 21.36% |
| | ISC->PR->PCS->SC | −0.0324 | 0.0113 | −0.0576 to −0.0135 | 5.94% |
| | ISC->PR->NPS->SC | −0.0179 | 0.0073 | −0.0345 to −0.0062 | 3.28% |
| **6, ISC -> SP** | | | | | |
| Total effect | ISC->SC | −0.481 | 0.0413 | −0.5623 to −0.3997 | 100.00% |
| Direct effect | ISC->SC | −0.2156 | 0.0427 | −0.2997 to −0.1316 | 44.82% |
| Indirect effects | ISC->PR->SC | −0.0612 | 0.0194 | −0.1041 to −0.0279 | 12.72% |
| | ISC->PCS->SC | −0.0578 | 0.0215 | −0.1051 to −0.0211 | 12.02% |
| | ISC->NPS->SC | −0.1072 | 0.0237 | −0.1563 to −0.0631 | 22.29% |
| | ISC->PR->PCS->SC | −0.0236 | 0.0091 | −0.0436 to −0.0086 | 4.91% |
| | ISC->PR->NPS->SC | −0.0156 | 0.0066 | −0.0304 to −0.0048 | 3.24% |

In general, the mediating effect consists of indirect effects generated by five pathways. First, the path of the indirect effect of SRA, SRC, and ISC on SC, SP through resilience. Second, the path of the indirect effect of SRA, SRC, and ISC on SC,SP through positive coping styles. Third, the path of the indirect effect of SRA, SRC, and ISC on SC, SP through negative coping styles. Fourth, the path of the indirect effect of SRA, SRC, and ISC on SC, SP through resilience and positive coping styles. Fifth, the path of the indirect effect of SRA, SRC, and ISC on SC, and SP through resilience and negative coping styles. Detailed results can be seen in Table 5 and Figures 2–7.

# Discussion

## Relationship Between Safety Stressors and Safety Performance of Coal Miners

We found that safety role ambiguity, safety role conflict, and interpersonal safety conflict had negative effects on both safety compliance and safety participation. This finding was consistent with Ye Gui.[88] This result indicates that SRA, SRC, and ISC are hindrance stressors, which can generate disruptive information and lead to a decrease in safety performance. In addition, we found that SRA has the greatest negative impact on safety compliance; it may be because SRA leads to coal miners not knowing their safety responsibilities when encountering safety issues, So the workers ignored the safety work they had to do. SRC has the greatest negative impact on safety participation, which may be due to the voluntary nature of safety participation. When two conflicting goals appear simultaneously, miners often abandon the non-mandatory task. ISC is the lowest impact factor of the three safety stressors. The impact of ISC on safety compliance and safety participation is the smallest among the three sources of stress, as it may cause negative emotions among miners,[129] leading to intentional violations or unwillingness to engage in voluntary safety work (such as actively reminding colleagues of unsafe behavior). However, the probability of this phenomenon occurring in reality is relatively

low. Negative emotions lead to miners intentionally violating regulations or not actively engaging in voluntary safety work (such as actively reminding their colleagues of unsafe behavior), but the probability of this phenomenon occurring is relatively low in reality.

## Mediating Role of Resilience

Resilience mediated all the examined relationships between safety stressors and safety performance. SRA, SRC, and ISC have significant negative effects on the resilience of miners. It means Workers have consumed this positive psychological resource to cope with stressors.[5,81] However, Resilience has a positive impact on safety compliance and safety participation. It means that resilience has become a "buffer" between safety stressors and safety performance. This phenomenon can be explained by the Social Cognitive Theory (SCT)[130], individuals can guide their behavior through their subjective characteristics and then influence the environment. Therefore, the result enlightens us to strengthen the resilience of coal miners such as providing regular psychological training to miners, organizing psychological relaxation activities, and imparting psychological relaxation techniques, which is very necessary.

## Mediating Role of Coping Styles

Coping styles play a mediating role in the relationship between safety stressors and safety performance. SRA, SRC, and ISC have a negative effect on the positive coping styles of miners and have a positive effect on the negative coping styles. The pressure imbalance model[107] can explain this phenomenon, when an individual is under stress, in order to maintain internal balance, they will use their resources to balance and choose different coping styles to compensate. Therefore, bearing stress can lead to a decrease in individual resources, leading to negative coping styles. On the contrary, the more resources an individual possesses, the more they will adopt positive coping styles for difficulties and challenges.[131] In addition, we found that positive coping styles have a positive impact on safety compliance and safety compliance, while negative coping styles have a negative impact on safety compliance and safety compliance, which is consistent with previous research findings.[110] It means that positive coping styles will encourage workers to increase their work enthusiasm and pay more attention to safety issues at work. Negative coping styles can lead to the opposite outcome. Therefore, SRA, SRC, and ISC can affect the safety performance of miners through coping styles.

## Multiple-Step Mediating Effect of Resilience and Coping Styles

This study found that safety stressors can affect safety performance of miners through a multiple-step mediated effect of resilience and coping styles. This result indicates that miners tend to consume individual psychological resilience to cope with safety stressors, which encourages them to choose positive coping styles to solve problems[132] and prevents them from choosing negative coping styles, thereby improving safety performance. At the same time, when the psychological resilience resources of workers are insufficient to help miners cope with safety pressures, it can lead to workers adopting negative coping styles, such as choosing to avoid and give up,[133] thereby reducing safety performance.

The above results clearly verify the pathways through which three sources of safety stressors affect safety performance through the resilience and coping styles of miners. Especially based on the analysis of the mediating effect of resilience, the role of coping styles in this process has been discovered, providing theoretical support for coal mining enterprises to propose safety management policies and ensure safety production. Specifically, first, coal mining enterprises resilience exercises and training activities to improve the ability of miners to cope with safety stressors. Secondly, special attention should be paid to workers who repeatedly adopt negative coping styles (such as evading safety inspections, passively treating participation in safety training, etc.), which means that their resilience has already or will been exhausted, and the intensity of resilience training should be increased, And introduce other ways to promote resilience, such as humanistic care or emotional support, to provide effective assistance for coal mine safety production.

# Limitations

Some limitations of this study should be mentioned. First of all, the study was a cross-sectional study, which only examined the relationship between variables at a certain time point, and cannot verify the dynamic development relationship and clear causal relationship. In the future, longitudinal or crossover studies can be used to explore the

mechanism of action between variables. Secondly, the generalizability of results in this study might be limited as this study only surveyed coal miners in Shaanxi Province. Future studies may consider expanding the sample to more regions and adopting more random sampling methods. Thirdly, this study has known that resilience and coping styles play a multiple-step mediating role between safety stressors and safety performance, and there are studies noticed that Positive coping styles can enhance positive emotions and lead to positive outcomes.[111,112] Whether emotion has also effect on the relationship between safety stressors, resilience, coping styles and safety performance need further research.

## Conclusion

This study investigated the safety stressors (SRA, SRC, and ISC), resilience, coping styles (PCS and NCS), and safety performance (SC and SP) of coal miners. The results showed that safety role ambiguity, safety role conflict, and interpersonal safety conflict negatively affected workers' safety compliance and safety participation. Resilience and coping styles (PCS and NCS) were found to mediate the relationship between safety stressors (SRA, SRC, and ISC) and safety compliance (SC and SP), respectively. And resilience and coping styles (PCS and NCS) also played a multiple-step mediating role in the effect of safety stressors (SRA, SRC, and ISC) on coal miners' safety performance (SC and SP). This result provides some theoretical support and guidance for the research and intervention of coal mine safety performance and has great significance for coal mining enterprises to formulate safety management policies and reduce production accidents.

## Data Sharing Statement

The datasets generated for this study are available on request to the corresponding author.

## Ethics Approval and Consent to Participate

All methods were carried out in accordance with Declaration of Helsinki. Written informed consent was obtained before data collection from the participants. This study was approved by the ethics committee of Academic and Ethics Committee of Xi'an University of science and technology. (Approval number: XUSTETHP002022040122).

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## Disclosure

The authors declare that they have no conflicts of interest.

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