

## ORIGINAL ARTICLE

# Prevalence of pneumoconiosis among young adults aged 24-44 years in a heavily industrialized province of China

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**Abstract**

**Objectives:** The purposes of this study were to clarify (i) the prevalence of pneumoconiosis among young adults and (ii) the factors associated with pneumoconiosis among young adults to explore targeted solution for control of pneumoconiosis among young adults (aged 24-44 years).

**Methods:** The new cases diagnosed from 2001 to 2015 (extracted from the National Occupational Disease and Occupational Health Information Monitoring System) were involved in this research, including information of employer, patient's name, date of birth, gender, date of diagnosis, first year of dust exposure, duration of exposure, aggregation etc

**Results:** A total of 1519 pneumoconiosis cases were diagnosed among young adults (21.6% of overall cases). Silicosis was the most common type with acute process of disease. Compared with overall cases, the young patients had shorter duration of exposure, more stage II/III cases and higher aggravation rate; and were even more concentrated in small and medium enterprises where more migrant workers were employed and insufficient protective measures were used. Without further regulation, the prevalence of pneumoconiosis among young adults would bring not only disease suffering for 3000 individuals and their families, but also an annual economic loss up to 180 million yuan for Hebei province till 2025.

**Conclusions:** As a typical heavily industrialized province of China, Hebei has severe situation on pneumoconiosis among young adults. Special attention and effort on silica-contacting industries, small and medium enterprises, and migrant workers should be focused in future occupational supervision and regulation among young adults.

**KEYWORDS**

pneumoconiosis, silicosis, young adult

## 1 | INTRODUCTION

Pneumoconiosis, an occupational disease (OD) mainly with diffuse pulmonary fibrosis, is caused by long-term inhalation and deposition of mineral dust into the lungs.<sup>1</sup> China is

one of those countries with severe situation on pneumoconiosis around the world.<sup>2</sup> In recent years, more than 80% of the new-reported OD cases were pneumoconiosis, and an annual increase was observed as well. In 2016, about 28000 new pneumoconiosis cases were reported in China.<sup>3</sup> The prevalence of

pneumoconiosis caused direct and indirect economic losses of around 28 billion yuan (4.3 billion US dollars) for 1 year.<sup>4</sup>

In the progression of pneumoconiosis, the accumulated dust in lungs could cause inflammation of the alveoli, and eventually result in irreversible lung damage and even death.<sup>5</sup> At present, there is no curative treatment for pneumoconiosis. But pneumoconiosis is preventable with proper control of dust and individual protection. To monitor and control the prevalence of pneumoconiosis, regular examination of occupational health with diagnosis of pneumoconiosis was forced by the Law of Occupational Disease Prevention and Treatment (issued in 2001) in China. Usually, pneumoconiosis is a disease mostly affecting older workers with very long duration of dust exposure. However, from 1997 to 2009, the average duration of dust exposure among pneumoconiosis cases reduced from 21 to 15 years in China,<sup>6</sup> indicating that more young workers were suffering with pneumoconiosis. And the diagnosis in young adults indicate acute or accelerated disease.<sup>7</sup> As the most important labor source, the young adults create most abundant social wealth. Thus, the prevalence of pneumoconiosis in this population would result in heavy disease burden and enormous loss of labor forces.

Hebei is a typical industrialized province in North China. At the end of 2015, the total population of Hebei Province was 74.2 million.<sup>8</sup> With the acceleration of urbanization, the ratio of urban and rural populations was increased to 1.05:1 from 1:2.83 in 2000. Heavy industries (including mining, energy, construction, manufacturing, etc) have been the pillar industries. By the end of 2015, the output value of the mining, energy, construction, and manufacturing industries reached 1087.8, 178.1, 178.1, and 95.4 billion yuan, accounting for 36.2%, 5.9%, 5.9%, and 3.2% of the GDP of Hebei province; and the number of employees reached 228 thousand, 188 thousand, 818 thousand and 1.4 million, respectively. Pneumoconiosis, especially silicosis and CWP, has been the most prevalent category of OD in Hebei, and most of them were reported from the mining and manufacturing industries.<sup>3</sup> According to the national report of occupational diseases, about 93.9% of the reported pneumoconiosis cases were silicosis and CWP, and mainly concentrated in the mining and manufacturing industries. Therefore, Hebei province is a typical representative for study of pneumoconiosis epidemic of China. In recent years, the diagnosed patients tended to be younger which might bring serious health and economic burden. To explore targeted solution for pneumoconiosis control, we analyzed the prevalent characteristics among young adults from 2001 to 2015 in Hebei province.

## 2 | MATERIALS AND METHODS

### 2.1 | Study population

A total of 6739 pneumoconiosis cases reported in Hebei province from 2001 to 2015 were extracted from the

National Occupational Disease and Occupational Health Information Monitoring System (NODOHIMS). Through the NODOHIMS, pneumoconiosis cases from both regular occupational health examination and clinical patients are reported by professional physicians with diagnostic qualification of pneumoconiosis. Standardized reporting indicators (including information of employer, patient's name, date of birth, gender, date of diagnosis, first year of dust exposure, duration of exposure, aggregation etc) are applied in identification cards and affiliation information for collection of readily available and comparable data. And all the pneumoconiosis cases were reviewed and approved by centers for disease control and prevention (CDC) at county, city, provincial, and national levels to ensure the accuracy of data. With health monitoring connected with employment units (including agency codes, economic types, and size), the system enabled dynamic observation and follow-up reports of the reported cases.

According to references from the WHO<sup>9</sup> and US CDC,<sup>7</sup> young adults were defined as persons aged 18–44 years or 15–44 years. Meanwhile, the youngest pneumoconiosis cases reported in NODOHIMS is 24 years old. Thus, young adults aged from 24 to 44 years old were regarded as objects in this study.

### 2.2 | Diagnosis and category of pneumoconiosis

According to the Chinese “Diagnostic Criteria of Pneumoconiosis,” the occurrence of pneumoconiosis was identified primarily based on (i) history of occupational exposure with mineral dust, (ii) qualified radiographic film indicating pathological changes at lung, (iii) information of workplace investigation on occupational hygiene and epidemiology, and (iv) monitoring data of occupational health. The clinical manifestation and laboratory examination were concerned as reference. Moreover, other similar pulmonary diseases were excluded. And the diagnosis of pneumoconiosis was defined by more than three qualified physicians. The Chinese “Diagnostic Criteria of Pneumoconiosis” classified pneumoconiosis as stage I, II, or III according to the size, profusion, and distribution of opacities on chest X-ray, which is very similar with the classification system of International Labor Organization (ILO) criteria.<sup>10–12</sup> During the dynamic observation and follow-up reports, the pneumoconiosis cases classified in higher stage compared with initial diagnosis were defined as aggravation cases. Furthermore, based on the Chinese Occupation Disease Classification and Catalogue, the pneumoconiosis cases were divided into 13 categories, including silicosis, coal worker's pneumoconiosis (CWP), graphite pneumoconiosis, anthracosis, asbestosis, et al.

## 2.3 | Statistical analysis

All the enumeration data were expressed as case number and constituent ratio, and all the measurement data, including age at diagnosis and duration of exposure, were expressed as mean  $\pm$ SD. The intragroup difference of enumeration data and measurement data was analyzed by  $\chi^2$  test and one-way analysis of variance (ANOVA). LSD (least significant difference) test was used for the post hoc multiple comparison in ANOVA. Generalized linear regression model was applied for multivariate analysis of age at diagnosis and duration of exposure. Binary logistic regression model was used for multivariate analysis of aggravation. Autoregressive integrated moving average model (ARIMA) was applied for prediction of pneumoconiosis case number from 2016 to 2025. All statistical analysis was performed using SPSS software (version 22.0; SPSS Inc, Chicago, IL, USA).

The large, medium, and small-scale enterprises were defined according to the National Statistics Bureau of the People's Republic of China. The enterprises with more than 1000 employees and production value higher than 400 million yuan were defined as large-scale enterprises; the enterprises with  $300 \leq$  employee number  $<1000$  and 20 million yuan  $\leq$  production value  $<400$  million yuan were defined as medium-scale enterprises; the enterprises with employee number  $<300$  or production value  $<20$  million yuan were defined as small-scale enterprises.

## 3 | RESULTS

### 3.1 | Description of pneumoconiosis cases diagnosed in Hebei province from 2001 to 2015

As summarized in Table 1, a total of 6966 pneumoconiosis cases were diagnosed in Hebei province from 2001 to 2015. And 21.81% of the overall cases (1519 cases) were diagnosed among young adults aged from 24 to 44 years old. Silicosis and CWP were the most prevalent type of pneumoconiosis among all ages and age group 24-44. The majority of pneumoconiosis cases were diagnosed among males. For the overall cases, the total and silicosis cases showed an overall increase from 2001 to 2015, while the proportion of CWP decreased from 2008. By contrast, pneumoconiosis among young adults started a sharp increase from 2010 in total, silicosis, and CWP cases. The average duration of dust exposure among young patients (11.1 years) was 5.6 years shorter than that among all patients (16.9 years); and a higher proportion of stage II or III pneumoconiosis was reported in age group 24-44 (39.7%) comparing with all ages (31.5%). Moreover, the aggravation ratio among age group 24-44 (11.3%) was more than twice of that among overall cases (4.8%). For all ages, 61.1% of the pneumoconiosis cases, 77.7% of the silicosis cases, and 25.8% of the

CWP cases were reported from medium and small enterprises; for age group 24-44, 72.7% of the pneumoconiosis cases, 88.7% of the silicosis cases, and 45.8% of the CWP cases were diagnosed from small and medium enterprises. For both all ages and age group 24-44, the industry of non-ferrous metal mining and beneficiation reported most silicosis cases; and the industry of coal mining, washing, and beneficiation reported most CWP cases.

### 3.2 | Characteristics of pneumoconiosis diagnosed in young adults aged 24-44 years

As shown in Table 2, the average age at diagnosis among young adults was 40.0 years and the average duration of exposure was 11.1 years. From 2001 to 2015, a total of 172 patients (11.3%) aggravated to higher stage of pneumoconiosis. The age at diagnosis did not show significant difference between genders, but significantly longer duration of exposure and lower aggravation rate were found in female patients. Compared with silicosis cases (69.1%), the CWP cases (16.3%) and other cases (14.6%) had significantly longer duration of exposure and lower aggravation rate. Moreover, significantly shorter duration of exposure was observed among young adults with higher stage at diagnosis. The small and medium enterprises reported the majority of pneumoconiosis cases (72.7%) with significantly shorter duration of exposure and higher aggravation rate compared with large-scale enterprises. As shown in Table 3, the distribution of stage I, II, and III significantly varied across the different scale enterprises. About 73.3% of the cases were reported among individuals who were first exposed to dust after 1990. Along with increase of first dust-exposure year, the average age at diagnosis significantly decreased from 41.7 to 39.5 years, and the average duration of exposure decreased from 21.1 to 6.3 years. The aggravation rate generally increased from 1.6% to 15.3% for individuals with first dust exposure before 2000, while 6.3% aggravation was observed for patients exposed to dust after 2000 due to insufficient period for disease progression. Industry of mining and beneficiation of nonferrous metals reported most pneumoconiosis cases among young adults, followed by coal industry, ferrous metal industry, non-metallic mineral industry, and other industries. Mining and beneficiation of nonferrous metal and ferrous metal had significantly shorter duration of exposure and higher aggravation rate.

As shown in Table 4, the multivariate analysis of age at diagnosis, duration of exposure, and aggravation had similar result with the univariate analysis. Only the mining and beneficiation of ferrous metal industry showed significantly longer duration of exposure compared with mining and beneficiation of nonferrous metals after introducing "first year of dust exposure" in the model, while no significant difference was observed in univariate analysis (as shown in Table 3).

**TABLE 1** Description of Pneumoconiosis diagnosed in Hebei province from 2001 to 2015

	Pneumoconiosis in all ages			Pneumoconiosis in young adults aged 24-44		
	Total	Silicosis	CWP	Total	Silicosis	CWP
Total, n (% <sup>a</sup> )	6966	4541 (65.2)	1523 (21.9)	1519	1046 (68.9)	247 (16.3)
Gender, n						
Male	6791 (97.5)	4476 (98.6)	1519 (99.7)	1458 (96.0)	1027 (98.2)	247 (100.0)
Female	175 (2.5)	65 (1.4)	4 (0.3)	61 (4.0)	19 (1.8)	0 (0.0)
Year of diagnosis, n (% <sup>a</sup> )						
2001	481	168 (34.9)	36 (7.5)	95	29 (30.5)	5 (5.3)
2002	314	191 (60.8)	40 (12.7)	73	49 (67.1)	4 (5.5)
2003	218	141 (64.7)	13 (6.0)	75	63 (84.0)	4 (5.3)
2004	224	155 (69.2)	12 (5.4)	67	56 (83.6)	3 (4.5)
2005	376	288 (76.6)	66 (17.6)	91	85 (93.4)	3 (3.3)
2006	243	139 (57.2)	89 (36.6)	38	32 (84.2)	6 (15.8)
2007	296	164 (55.4)	59 (19.9)	93	73 (78.5)	3 (3.2)
2008	424	169 (39.9)	218 (51.4)	63	43 (68.3)	17 (27.0)
2009	384	175 (45.6)	179 (46.6)	62	49 (79.0)	5 (8.1)
2010	445	292 (65.6)	115 (25.8)	114	89 (78.1)	9 (7.9)
2011	394	264 (67.0)	88 (22.3)	121	79 (65.3)	20 (16.5)
2012	658	490 (74.5)	126 (19.2)	166	119 (71.7)	30 (18.1)
2013	700	519 (74.1)	140 (20.0)	141	81 (57.5)	42 (29.8)
2014	985	712 (72.3)	233 (23.7)	186	105 (56.5)	69 (37.1)
2015	824	674 (81.8)	109 (13.2)	134	94 (70.2)	27 (20.2)
Duration of dust exposure, year	16.7 ± 10.3	13.5 ± 9.7	22.9 ± 9.1	11.1 ± 6.6	9.1 ± 6.0	14.1 ± 6.1
Stage at diagnosis, n (%)						
Stage I	4768 (68.4)	2634 (58.0)	1307 (85.8)	917 (60.4)	543 (51.9)	176 (71.3)
Stage II	1444 (20.7)	1194 (26.3)	188 (12.3)	452 (29.8)	366 (35.0)	60 (24.3)
Stage III	754 (10.8)	713 (15.7)	28 (1.8)	150 (9.9)	137 (13.1)	11 (4.5)
TB cases, n (%)	203 (2.9)	168 (3.7)	22 (1.4)	40 (2.6)	35 (3.3)	3 (1.2)
Aggravated Cases, n (%)	336 (4.8)	293 (6.5)	18 (1.2)	172 (11.3)	154 (14.7)	3 (1.2)
Enterprise scale, n (%)						
Large	2707 (38.9)	1013 (22.3)	1130 (74.2)	415 (27.3)	119 (11.4)	134 (54.3)
Medium	2100 (30.1)	1559 (34.3)	280 (18.4)	500 (32.9)	373 (35.7)	80 (32.4)
Small	2159 (31)	1969 (43.4)	113 (7.4)	604 (39.8)	554 (53)	33 (13.4)
Industry type, n (%)						
Mining and beneficiation of nonferrous metals	1875 (26.9)	1860 (41.0)	6 (0.4)	551 (36.3)	548 (52.4)	1 (0.4)
Mining, washing and beneficiation of coal	1770 (25.4)	453 (10.0)	1303 (85.6)	266 (17.5)	65 (6.2)	197 (79.8)
Mining and beneficiation of ferrous metal	1285 (18.4)	1255 (27.6)	19 (1.2)	255 (16.8)	246 (23.5)	8 (3.2)
Manufacture of non-metallic mineral products	844 (12.1)	222 (4.9)	4 (0.3)	217 (14.3)	50 (4.8)	1 (0.4)
Other industries	1192 (17.1)	751 (16.5)	191 (12.5)	230 (15.1)	137 (13.1)	40 (16.2)

<sup>a</sup>percentage of silicosis or CWP in total pneumoconiosis.

**TABLE 2** Characteristics of pneumoconiosis diagnosed in young adults aged 24–44 years

	Diagnosed cases, n (%)	Age at diagnosis, year	Duration of Exposure, year	Aggravated Cases, n (% <sup>a</sup> )
Total	1519 (100%)	40.0 ± 3.7	11.1 ± 6.6	172 (11.3%)
<b>Gender</b>				
Male	1458 (96.0%)	40.0 ± 3.8	10.9 ± 6.6	168 (11.5%)
Female	61 (4.0%)	40.0 ± 3.3	15.2 ± 5.6	4 (6.6%)
F or $\chi^2$	—	0.0021	24.619	1.438
P-value	—	0.885	<0.001	0.231
<b>Pneumoconiosis type</b>				
Silicosis	1046 (69.1%)	40.1 ± 3.7	9.1 ± 6.0	154 (14.7%)
CWP	247 (16.3%)	40.3 ± 3.7	14.1 ± 6.1*	3 (1.2%)*
Others	226 (14.9%)	39.6 ± 4.1	16.9 ± 5.3*	15 (6.6%)*
F or $\chi^2$	—	2.154	205.308	42.118
P-value	—	0.116	<0.001	<0.001
<b>Stage at diagnosis</b>				
Stage I	917 (60.4%)	40.0 ± 3.7	12.4 ± 6.8	133 (14.5%)
Stage II	452 (29.8%)	39.9 ± 3.9	9.5 ± 6.1*	39 (8.6%)
Stage III	150 (9.9%)	40.9 ± 3.3*	8.0 ± 4.8*	—
F or $\chi^2$	—	4.191	50.146	9.514
P-value	—	0.015	<0.001	0.002
<b>Enterprise scale</b>				
Large	415 (27.3%)	40.1 ± 3.7	15.5 ± 6.2	23 (5.5%)
Medium	500 (32.9%)	39.9 ± 3.8	11.0 ± 6.4*	37 (7.4%)
Small	604 (39.8%)	40.1 ± 3.7	8.1 ± 5.3*	112 (18.5%)*
F or $\chi^2$	—	0.302	189.759	52.832
P-value	—	0.740	<0.001	<0.001
<b>First year of dust exposure</b>				
<1980	63 (4.1%)	41.7 ± 3.5	21.1 ± 4.3	1 (1.6%)
1980~	342 (22.5%)	41.2 ± 2.5	17.4 ± 5.6*	47 (13.7%)*
1990~	602 (39.6%)	39.7 ± 3.8*	10.5 ± 5.4*	92 (15.3%)*
2000~	512 (33.7%)	39.5 ± 4.2*	6.3 ± 3.3*	32 (6.3%)
F or $\chi^2$	—	21.125	455.102	30.463
P-value	—	<0.001	<0.001	<0.001
<b>Industry type</b>				
Mining and beneficiation of nonferrous metals	551 (36.27%)	40.2 ± 3.4	8.5 ± 5.6	102 (18.5%)
Mining, washing and beneficiation of coal	266 (17.5%)	40.5 ± 3.5	13.8 ± 6.4*	7 (2.6%)*
Mining and beneficiation of ferrous metal	255 (16.8%)	40.2 ± 3.7	8.3 ± 5.1	34 (13.3%)
Manufacture of non-metallic mineral products	217 (14.3%)	39.5 ± 3.9*	15.3 ± 5.8*	20 (9.2%)*
Other industries	230 (15.1%)	39.6 ± 4.4*	13.1 ± 7.4*	9 (3.9%)*
F or $\chi^2$	—	3.096	85.711	62.932
P-value	—	0.015	<0.001	<0.001

<sup>a</sup>percentage of aggravated cases in diagnosed cases.\* $P < 0.05$  (pneumoconiosis type: compared to silicosis; stage at diagnosis: compared to stage I; enterprise scale: compared to large scale; first year of dust exposure: compared to <1980; industry type: compared to mining and beneficiation of nonferrous metals).



Enterprise scale	Stage at diagnosis*		
	Stage I, n (%)	Stage II, n (%)	Stage III, n (%)
Large	317 (76.4)	84 (20.2)	14 (3.4)
Medium	298 (59.6)	151 (30.2)	51 (10.2)
Small	302 (50.0)	217 (35.9)	85 (14.1)

\*  $\chi^2$ : 77.427;  $P < 0.001$ .

### 3.3 | Prediction of economic losses caused by prevalence of pneumoconiosis in young adults aged 24-44 years

Based on the prevalence trend in pneumoconiosis among young adults from 2001 to 2015, an annual occurrence of around 150 cases aged 24-44 was predicted throughout the following decade. According to our previous research, the average age of death was  $75.8 \pm 8.2$  among pneumoconiosis patients in Hebei, and the average course of the disease was 35.8 years.<sup>13</sup> Theoretically, the cases of pneumoconiosis diagnosed among young adults after 2001 should still be alive till 2025, and more than 3000 pneumoconiosis patients will be accumulated. Referring to the research of Zhang et al,<sup>14</sup> the direct and indirect burden of CWP were 24 108 and 35 977 yuan per capita for 1 year, respectively. Thus, the pneumoconiosis among young adults would bring an annual economic loss up to 180 million yuan for Hebei province till 2025.

## 4 | DISCUSSION

The occupational health is important to the socio-economic development of all the countries. High-quality monitoring data on occupational diseases are essential for estimation of regional and national burden, which could not only help policy-makers to improve priorities and targets in health policies, but also make employers, social security institutions, and other stakeholders to fulfill their obligations. At present, only a few countries (USA, United Kingdom, New Zealand, Germany, Finland, etc) have established comprehensive occupational report system.<sup>15</sup> China established NODOHIMS from 1980s, and improved with standardization of reporting indicators in 2006.<sup>16</sup>

Similar with other industrialized provinces in China, the number of pneumoconiosis cases increased with rapid economic growth in Hebei province. But unlike the provinces with abundant coal industries (like Shanxi, Hubei, and Hunan),<sup>4,17</sup> the occurrence of CWP started to decrease from 2008 due to the shutdown of small coal mines and structural improvement of coal industry in Hebei. At the same time, silicosis from nonferrous metals, ferrous metal, non-metallic minerals, and other industries became the most predominant

**TABLE 3** Distribution of pneumoconiosis stage at diagnosis in enterprises of different scale

type of pneumoconiosis. Compared with CWP, silicosis had shorter duration of exposure, more cases with high stage at diagnosis, and higher aggravation rate, implying that silica dust is currently the most dangerous occupational hazards in Hebei province. From 2001 to 2015, more than one-fifth of the pneumoconiosis cases were found in young adults aged 24-44. To our knowledge, pneumoconiosis caused by mineral dust are generally considered to have long latencies (10-20 years) until clinically apparent.<sup>18</sup> The average duration of exposure reported in Chinese national investigation was 20 years.<sup>6</sup> The significant growth of low-age pneumoconiosis from 2010 was probably caused by the free supplementary health check for migrant workers supported by the government and the concentrated diagnosis of patients, who started to contact occupational dust after 1990, when heavy industries in Hebei Province began to develop rapidly. The relatively short average duration of exposure, more stage II/III cases, and more aggravated cases were observed among the young pneumoconiosis (especially silicosis) patients underlined the accelerated disease procedure in young adults, which might due to the preference of young adults in frontline jobs with high exposure to dust. Without further regulation, the prevalence of pneumoconiosis among young adults would bring not only disease suffering for 3000 individuals and their families, but also an annual economic loss up to 180 million yuan for Hebei province till 2025. All these characteristics suggested that the government should pay more attention to the prevalence of pneumoconiosis in young adults.

The phagocytosis of silica dust in the lung causes lysosomal damage, which activates the NALP3 inflammasome and triggers the inflammatory cascade with subsequent fibrosis.<sup>19</sup> Even after the patient is no longer exposed to silica dust, the impairment of lung function still keeps progressing. In particular, low-aged or acute silicosis could increase the risk of pulmonary tuberculosis,<sup>19</sup> which would result in poor prognostic outcome of pneumoconiosis with high aggravation rate and fatality rate.<sup>20</sup> According to "China Occupational Exposure Limits for Hazardous Factors in Workplace," the upper limit of the total dust concentration (free SiO<sub>2</sub> content <10%) is 4 mg/m<sup>3</sup>, and the upper limit of respirable dust concentration is 1.5 mg/m<sup>3</sup>. An investigation of 36 cement manufacturing enterprises in 2013 reported that the dust concentration exceeded the national limit in 86% enterprises.<sup>21</sup> Thus, supervision over

**TABLE 4** Multivariate linear regression analysis of related factors of age at diagnosis and duration of exposure, and multivariate logistic regression analysis of related factors of aggravation in young adults aged 24–44 years

	Age at diagnosis		Duration of Exposure		Aggravation	
	$\beta$ (95% CI)	<i>P</i> -value	$\beta$ (95% CI)	<i>P</i> -value	$\beta$ (95% CI)	<i>P</i> -value
Gender						
Male	0.00	—	0.00	—	0.00	—
Female	0.12 (−0.90, 1.13)	0.822	1.02 (−2.17, 0.13)	0.083	0.64 (−0.49, 1.76)	0.269
Pneumoconiosis type						
Silicosis	0.00	—	0.00	—	0.00	—
CWP	0.12 (−0.63, 0.87)	0.751	2.58 (1.74, 3.43)	<0.001	1.56 (0.20, 2.92)	0.025
Others	−0.46 (−1.28, 0.37)	0.276	2.58 (1.65, 3.51)	<0.001	0.29 (−0.61, 1.20)	0.527
Stage at diagnosis						
Stage I	0.00	—	0.00	—	—	—
Stage II	−0.01 (−0.44, 0.41)	0.949	−0.57 (−1.05, −0.09)	0.019	—	—
Stage III	1.14 (0.50, 1.78)	<0.001	−0.80 (−1.52, −0.07)	0.031	—	—
Enterprise scale						
Large	0.00	—	0.00	—	0.00	—
Medium	−0.27 (−0.82, 0.28)	0.334	−1.05 (−1.66, −0.43)	0.001	0.47 (−0.18, 1.12)	0.159
Small	0.00 (−0.58, 0.58)	0.993	−2.37 (−3.02, −1.71)	<0.001	−0.64 (−1.25, −0.03)	0.04
First year of dust exposure						
<1980	0.00	—	0.00	—	0.00	—
1980~	−1.40 (−2.42, −0.39)	0.007	−1.50 (−2.66, −0.35)	0.01	−1.85 (−3.90, 0.20)	0.077
1990~	−3.19 (−4.21, −2.17)	<0.001	−7.31 (−8.46, −6.15)	<0.001	−1.65 (−3.70, 0.41)	0.116
2000~	−3.51 (−4.55, −2.46)	<0.001	−12.04 (−13.22, −10.86)	<0.001	−0.72 (−2.80, 1.37)	0.5
Industry type						
Mining and beneficiation of nonferrous metals	0.00	—	0.00	—	0.00	—
Mining, washing and beneficiation of coal	0.16 (−0.64, 0.96)	0.698	2.68 (1.77, 3.58)	<0.001	1.02 (0.05, 1.99)	0.038
Mining and beneficiation of ferrous metal	0.27 (−0.28, 0.82)	0.343	2.02 (1.40, 2.65)	<0.001	0.34 (−0.11, 0.78)	0.139
Manufacture of non-metallic mineral products	−1.21 (−2.07, −0.36)	0.006	1.16 (0.19, 2.13)	0.019	0.32 (−0.47, 1.12)	0.428
Other industries	−0.73 (−1.34, −0.11)	0.020	2.91 (2.22, 3.61)	<0.001	1.39 (0.65, 2.13)	<0.001

silica-contacting industries should be strengthened in urgent. Furthermore, although CWP was less dominative and destructive than silicosis in Hebei, a growth of CWP diagnosed in young adults was observed in this research, to which the government and supervising departments should pay attention.

As aforementioned, the Law of Occupational Disease Prevention and Treatment was issued in China in 2001 with forced regular occupational health examination. Till the end of 2006, health inspection agencies were setup in 90% of cities and counties, and irregular inspections were carried out by government.<sup>22</sup> However, up to 39.7% of the patients were still found to be stage II or III at the first diagnosis, indicating that the supervision was not enough. Although some large

state-owned enterprises have established their own health and safety department for surveillance of occupational health and monitoring of environmental exposure, many employers of small and medium enterprises give insufficient attention to pneumoconiosis prevention. Through our previous investigation, 63% of the dust contacting population was from small and medium-scale enterprises, which accounted for 97% of the total enterprise amount. Most small and medium-scale enterprises have poor working conditions with few basic dust-proof measures, and did not provide regular health examination, especially for migrant workers who were always hired for dangerous positions and do not have awareness and knowledge of self-protection. An investigation of stone



**FIGURE 1** Estimation and prediction of annual economic loss caused by pneumoconiosis cases among young adults aged 24–44 from 2001 to 2025

processing enterprises indicated that 30% of the workers did not wear dust mask, and 65% of the worker did not wear qualified dust mask in small and medium-scale enterprises.<sup>23</sup> Thus, the supervision and improvement of occupational protection should be specifically focused on small and medium-scale enterprises, especially on migrant workers.

## 5 | CONCLUSION

Prevalence of pneumoconiosis among young adults aged 24–44 has become an important public health problem in Hebei province. Data from reporting system of occupational disease indicated that pneumoconiosis tended to be accelerated among young pneumoconiosis patients due to the high proportion of silicosis and the insufficient occupational protect in small and medium enterprises. To reduce the abundant disease suffering and economic loss caused by pneumoconiosis cases diagnosed in young adults, special attention and effort on silica-contacting industries, small and medium enterprises, and migrant workers should be focused in future supervision and regulation. Beyond clearer obligations and tougher health policies, more education of pneumoconiosis protection should be taken by governments, educational institutions, and media. Research and development of new dust-proof technologies and products should be encouraged and funded with priority. For workers contacting especially high concentration of dust, the use of dust-proof equipment should be combined with short work hours or proper shift system to reduce the hazards.<sup>19</sup> For developing countries like China, control and prevention of pneumoconiosis could not be achieved within a short time, and there is still a long way to go.

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## DISCLOSURE

*Approval of the research protocol:* Health Commission of Hebei province. *Informed consent:* N/A. *Registry and the registration no. of the study/trial:* N/A. *Animal studies:* N/A.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

Chun-Xian Zhao (conception, design and manuscript writing); Jian-Guo Li (manuscript revising); Jun-Qin Zhao (data analysis and manuscript writing).

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