

# BMJ Open Characteristics and factors associated with morbidity of migrant workers with pneumoconiosis: a cross-sectional study

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## ABSTRACT

**Objectives** To better understand the characteristics of migrant workers with pneumoconiosis in China, and the factors that contribute to their morbidity.

**Design** A cross-sectional study.

**Setting** This study was conducted in Shanghai, Nanning and Shenzhen, China, between December 2020 and December 2021.

**Participants** There were 601 questionnaires that were analysed involving 198 migrant workers with pneumoconiosis, 205 workers with pneumoconiosis in state-owned enterprises (SOEs) and 198 other migrant workers with non-pulmonary occupational diseases.

**Outcome measures** Epidemiological characteristics of pneumoconiosis among migrant workers were determined. Using logistic regression, we examined the factors related to the morbidity of pneumoconiosis in migrant workers.

**Results** The response rate was 93.27%. In comparison with pneumoconiosis among SOE workers, the number of migrant workers with pneumoconiosis who first encountered dust exposure between the ages of 30 and 44 years and had an accumulated dust exposure of 1–10 years was proportionately greater. Migrant workers who developed pneumoconiosis between 18 and 32 years and those who had stage III pneumoconiosis were proportionately greater ( $p < 0.05$ ). Compared with migrant workers with non-pulmonary occupational diseases, six factors were associated with the morbidity of pneumoconiosis in migrant workers. Risk factors were dust exposure (OR=499.25, 95% CI: 68.33 to 3647.59) and someone smoking in the workplace (OR=5.67, 95% CI: 2.18 to 14.78). Protective factors were regular sleeping hours per night, (OR=0.23, 95% CI: 0.09 to 0.60), excellent ventilation (OR=0.09, 95% CI: 0.01 to 0.65), rules and regulations (OR=0.22, 95% CI: 0.07 to 0.66) and post-departure medical examinations (OR=0.24, 95% CI: 0.09 to 0.63).

**Conclusions** Compared with SOE workers with pneumoconiosis, migrant workers are exposed to dust at an earlier age, but for shorter duration, display morbidity at an earlier age and have a higher proportion of tertiary pneumoconiosis. They are predominantly male and have inadequate employment stability and medical insurance. Occupational health check-ups and management systems are inadequate.

## INTRODUCTION

Occupational pneumoconiosis is a chronic interstitial lung disease induced by continuous

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Our study chose representative hospitals from three cities and investigated many new cases and different stages of pneumoconiosis.
- ⇒ The actual study used migrant workers with non-pulmonary occupational diseases as a control group, which somewhat reduces the control group's comparability.
- ⇒ The questionnaire included no mention of dust concentrations.
- ⇒ Misclassification of exposures and outcomes may introduce bias into the study.

inhalation of respirable mineral dust and its retention in the lungs, mostly resulting in widespread fibrosis of the lung tissue.<sup>1</sup> There are 13 types of occupational pneumoconiosis (based on the nature and types of dust) in China.<sup>1</sup> There are three basic types of lesions, namely pneumoconiosis nodules, dust macules and diffuse coniofibrosis. The stages of pneumoconiosis are based on the severity of the three types of lesions. In both 2018 and 2020, new instances of occupational pneumoconiosis accounted for more than 80% of all new cases of all occupational disorders in China. The Global Burden of Disease (2019) showed an estimated 10 200.8 (95% CI: 8049.62 to 13 567.42) cases of pneumoconiosis-related deaths in 2019 in China, signalling the emergence of pneumoconiosis as a significant public health issue in China.<sup>2</sup>

Migrant workers are individuals whose household registration remains in rural areas and who work in non-agricultural businesses in the local area or who work outside of their household location for at least 6 months during the year.<sup>3</sup> The household registration system in China, classifying each person as a rural or an urban resident, is a major means of controlling population mobility and determining eligibility for state-provided services and welfare.<sup>4</sup> Pneumoconiosis is a particularly serious disease among migrant workers. By

**Table 1** Demographic characteristics of migrant workers with pneumoconiosis compared with state-owned enterprise workers with pneumoconiosis and migrant workers with non-pulmonary occupational diseases

Variables N (%)	Migrant workers with pneumoconiosis n=198	State-owned enterprise workers with pneumoconiosis n=205	Migrant workers with non-pulmonary occupational diseases n=198
Gender			
Men	195 (98.48)	202 (98.54)	158 (79.80)*
Women	3 (1.52)	3 (1.46)	40 (20.20)
Age			
21–40	25 (12.63)	11 (5.37)†	37 (18.69)
41–60	155 (78.28)	100 (48.78)†	149 (75.25)
61–80	18 (9.09)	78 (38.05)†	12 (6.06)
≥80	0 (0.00)	16 (7.80)†	0 (0.00)
Household registration			
Rural	198 (100.00)	75 (36.59)	198 (100.00)
Cities and towns	0 (0.00)	130 (63.41)	0 (0.00)
Body mass index			
<18.5	20 (10.10)	7 (3.41)†	9 (4.55)*
18.5–24.9	119 (60.10)	135 (65.85)	111 (56.06)
25–29.9	54 (27.27)	60 (29.27)	66 (33.33)
≥30	5 (2.53)	3 (1.46)	12 (6.06)
Education			
Tertiary and above	1 (0.51)	7 (3.41)†	10 (5.05)*
Secondary/high school/vocational high school	16 (8.08)	39 (19.02)†	69 (34.85)*
Junior high school	92 (46.46)	97 (47.32)	74 (37.37)
Primary school and below	89 (44.95)	62 (30.24)†	45 (22.73)*
Smoking			
Yes	33 (16.67)	63 (30.73)†	41 (20.71)*
Quit smoking	93 (46.97)	76 (37.07)†	10 (5.05)*
No	72 (36.36)	66 (32.20)	147 (74.24)*
Someone smoking in the workplace			
Yes	165 (83.33)	142 (69.27)†	82 (41.41)*
No	33 (16.67)	63 (30.73)	116 (58.59)
Drinking			
Yes	68 (34.34)	78 (38.05)†	22 (11.11)*
No	130 (65.66)	127 (61.95)	176 (88.89)
Regular sleeping hours per night			
Yes	70 (35.35)	135 (65.85)†	170 (85.86)*
No	128 (64.65)	70 (34.15)	28 (14.14)
Average monthly income (¥)			
<3000	125 (63.13)	66 (32.20)†	45 (22.73)*
3000–6000	52 (26.26)	96 (46.83)†	117 (59.09)*
6000–9000	15 (7.58)	41 (20.00)†	34 (17.17)*
≥9000	6 (3.03)	2 (0.98)	2 (1.01)
Regular employment			
Yes	81 (40.91)	205 (100.00)	159 (80.30)*
No	117 (59.09)	0 (0.00)	39 (19.70)

\*Migrant workers with pneumoconiosis versus migrant workers with non-pulmonary occupational diseases:  $p < 0.05/n$ , where  $n$  is the total number of Bonferroni correction tests.  
†Migrant workers with pneumoconiosis versus state-owned enterprise workers:  $p < 0.05/n$ , where  $n$  is the total number of Bonferroni correction tests.

the end of 2020, China's migrant workers were expected to reach roughly 290 million.<sup>3</sup> Due to under-reporting of pneumoconiosis in some medical institutions,<sup>5</sup> or lack of diagnosis of occupational disorders in some migrant

workers,<sup>6,7</sup> some cases of migrant pneumoconiosis are not included in official data, and the true number of migrant workers sick with pneumoconiosis may be significantly higher.

**Table 2** Mobility and insurance for migrant workers with pneumoconiosis

Variables	Number of people N=117	Composition ratio (%)
Time spent working away (years)		
1–10	54	46.15
11–20	28	23.93
21–30	29	24.79
31–40	6	5.13
Number of job changes		
1	30	25.64
2	31	26.50
>2	56	47.86
Signing of employment contracts		
Yes	25	21.37
No	92	78.63
Medical insurance		
Yes	10	8.55
No	107	91.45
Longest duration of employment (years)		
0–2	45	38.46
2–4	27	23.08
4–6	26	22.22
6–8	19	16.24

Existing studies have already shown that gender, education, working hours, and rules and regulations are factors associated with the morbidity of pneumoconiosis.<sup>8–10</sup> A cohort study of iron ore dust exposure discovered that both dust exposure and smoking are strongly linked with pneumoconiosis occurrence.<sup>11</sup> However, these have been found to be from general dust-exposed people, and fewer studies have examined the factors associated with the morbidity of pneumoconiosis in migrant workers. The characteristics of migrant workers in China stand out, with inadequate employment stability, a low proportion of signed labour contracts and a low proportion of social insurance participation.<sup>12</sup> Due to these characteristics, the morbidity of pneumoconiosis among migrant workers may be influenced by different factors, which remain uncharacterised due to the lack of research on this topic. Accordingly, our aim was to better understand the characteristics of migrant workers with pneumoconiosis in China, as well as the factors that contribute to pneumoconiosis-related morbidity.

## METHODS

### Study design

A cross-sectional study design was used to thoroughly investigate the characteristics and factors associated with pneumoconiosis morbidity among migrant workers. Participants were questioned face-to-face or over the phone, and under the supervision of their physicians. This study conducted a pretesting of the questionnaire in December 2020 at an occupational disease hospital

in Shenzhen. The pretesting determined whether the participants understood the questions and whether they were able to complete the questionnaire. To obtain as adequate a sample size as possible, we used convenience sampling. Sample size calculation was done using PASS V.15 (Tests for Two Proportions). Published literature shows that the exposure rate to inadequate ventilation in the general occupational population is approximately 42%.<sup>13</sup> Let  $\alpha=0.05$  and power=0.90. Taking the lowest OR for risk factors=2.0, the required sample size was calculated to be 348. The sample was expanded by 10% to take into account the response rate and sampling error. In summary, the total sample size for this study was 383 cases.

### Setting

Between December 2020 and December 2021, a survey was conducted in three Chinese cities: Shanghai, Nanning and Shenzhen. Shanghai Pulmonary Hospital, Guangxi Zhuang Autonomous Region Institute of Occupational Disease Control and Prevention, and Shenzhen Institute of Occupational Disease Control and Prevention, all specialising in occupational diseases, were selected as the survey sites in their respective cities. They are three hospitals of different levels and come from three cities with varying economic conditions and pneumoconiosis prevalence, ensuring a representative sample.

### Participants

We surveyed 601 study participants, involving 198 migrant workers with pneumoconiosis, 205 workers with pneumoconiosis who worked in state-owned enterprises (SOEs) and 198 migrant workers with occupational but non-pulmonary diseases. The shared inclusion criteria for migrant workers with pneumoconiosis and SOE workers with pneumoconiosis were that they met the diagnostic criteria specified in China's GBZ70-2015 *Occupational Pneumoconiosis Diagnosis*.<sup>1</sup> The former also required that the migrant workers had a non-state enterprise as an employer, whereas the latter required a state enterprise to be the employer. Workers without pneumoconiosis were migrant workers who had an occupational but non-pulmonary disease, and had an employer who was not an SOE. Common exclusion criteria for all three groups included those who could not understand the questionnaire well for various reasons, and those who did not obtain informed consent.

### Variables

The questionnaire included general information, information about the employer, history of dust exposure, history of pneumoconiosis and labour protection.

### Bias

Selection bias can occur when convenience sampling is used. This study controlled for selection bias in three phases: design, implementation and analysis. In the design phase, strict inclusion and exclusion criteria were established, and three different levels of hospitals were selected. Throughout the implementation phase,

**Table 3** Dust exposure of migrant workers with pneumoconiosis compared with state-owned enterprise workers with pneumoconiosis and migrant workers with non-pulmonary occupational diseases

Variables N (%)	Migrant workers with pneumoconiosis n=198	State-owned enterprise workers with pneumoconiosis n=205	Migrant workers with non-pulmonary occupational diseases n=198
Dust exposure			
Yes	198 (100.00)	205 (100.00)	56 (28.28)*
No	0 (0.00)	0 (0.00)	142 (71.72)
Age of commencement of dust exposure			
15–29	104 (52.53)	137 (66.83)†	28 (51.85)
30–44	79 (39.90)	58 (28.29)†	21 (38.89)
45–59	15 (7.58)	10 (4.88)	5 (9.26)
Duration of dust exposure			
1–5	53 (26.77)	20 (9.76)†	19 (33.93)
6–10	79 (39.90)	41 (20.00)†	15 (26.79)
11–15	26 (13.13)	33 (16.10)	13 (23.21)
≥16	40 (20.20)	111 (54.15)†	9 (16.07)
Dust type (%)‡			
Mineral dust	116 (58.59)	136 (66.34)	8 (14.29)*
Metallic dust	19 (9.60)	38 (18.54)†	23 (41.07)*
Artificial inorganic dust	44 (22.22)	29 (14.15)†	8 (14.29)
Plant-based dust	0 (0.00)	0 (0.00)	1 (1.79)
Artificial organic dust	1 (0.51)	0 (0.00)	16 (28.57)*
Mixed dust	18 (9.09)	2 (0.98)†	0 (0.00)*
Smoking during dust exposure			
Yes	96 (48.48)	87 (42.44)	8 (14.29)*
No	102 (51.52)	118 (57.56)	48 (85.71)

\*Migrant workers with pneumoconiosis versus migrant workers with non-pulmonary occupational diseases:  $p < 0.05/n$ , where n is the total number of Bonferroni correction tests.  
†Migrant workers with pneumoconiosis versus state-owned enterprise workers:  $p < 0.05/n$ , where n is the total number of Bonferroni correction tests.  
‡Mineral dust includes quartz, asbestos, talc, coal, rare earths, etc. Metallic dust includes lead, manganese, iron, etc and their compounds. Artificial inorganic dust such as macadam, cement, glass fibre, etc. Plant-based dust such as cotton, hemp, grains, etc. Artificial organic dust such as synthetic resins, rubber, etc.

controls with different stages of pneumoconiosis and multiple departments were investigated. In the analysis phase, stratified analysis and multifactorial analysis were used to control for the role of confounding factors.

### Statistical methods

The study participants were divided into three groups, including migrant workers with pneumoconiosis, migrant workers with non-pulmonary occupational diseases and SOE workers with pneumoconiosis. Migrant workers with non-pulmonary occupational diseases served as a control group for the purpose of examining the factors related to the morbidity of pneumoconiosis in migrant workers. To better understand the characteristics of pneumoconiosis among migrant workers, SOE workers with pneumoconiosis were employed as a control.

For analysis, quantitative variables were transformed into qualitative variables for analysis, including age, time spent working away (years), longest duration of employment (years), age of commencement of dust exposure and age of morbidity. The transformation is based on the range of quantitative variables and the number of groups to be classified. The  $X^2$  test or Fisher's exact test was used to determine if the differences in composition ratios between groups were statistically significant. A

two-way comparison between groups was performed using Bonferroni correction. Stratification was used to analyse certain qualitative variables. Having pneumoconiosis as the dependent variable, variables with statistically significant ( $p < 0.05$ ) findings in the univariate between-group analyses were chosen from migrant workers with pneumoconiosis versus migrant workers with non-pulmonary occupational diseases. After combining professional judgements (using a directed acyclic graph (DAG)), variables were included in a dichotomous multifactor logistic regression model for analysis (Forward Selection (Likelihood Ratio)). The DAG was drawn by using DAGitty web-based software (<http://www.dagitty.net>).<sup>14</sup> We addressed the missing data by returning to the study participants.

### Patient and public involvement

Patients and members of the public were not involved in the design of this study.

### RESULTS

In this study, 654 people were surveyed and 610 responded, with a response rate of 93.27%. After unified verification and collation of the questionnaires, the final number of questionnaires included in the statistical

**Table 4** Comparison of pneumoconiosis history in migrant workers with pneumoconiosis and state-owned enterprise workers with pneumoconiosis

Variables N (%)	Total N=403	Migrant workers with pneumoconiosis n=198	State-owned enterprise workers with pneumoconiosis n=205
Age of morbidity			
18–32*	29 (7.20)	20 (10.10)	9 (4.39)
33–47	204 (50.62)	109 (55.05)	95 (46.34)
48–62*	160 (39.70)	65 (32.83)	95 (46.34)
≥63	10 (2.48)	4 (2.02)	6 (2.93)
Stage			
I*	249 (61.79)	106 (53.54)	143 (69.76)
II	93 (23.08)	50 (25.25)	43 (20.98)
III*	61 (15.14)	42 (21.21)	19 (9.27)
Type of pneumoconiosis			
Silicosis*	272 (67.49)	149 (75.25)	123 (60.00)
Coal workers' pneumoconiosis*	51 (12.66)	17 (8.59)	34 (16.59)
Welders' pneumoconiosis*	20 (4.96)	3 (1.52)	17 (8.29)
Castor's pneumoconiosis*	11 (2.73)	0 (0.00)	11 (5.37)
Other types of pneumoconiosis	49 (12.16)	29 (14.65)	20 (9.76)

\*P<0.05/n, where n is the total number of Bonferroni correction tests.

analysis was 601, with an effective rate of 98.52%. The migrant workers with pneumoconiosis consisted of 195 men (98.48%). The proportion of migrant workers with pneumoconiosis who had primary school and below and had a monthly income of less than ¥3000 was higher than for SOE workers with pneumoconiosis. Men, body mass index <18.5, primary school and below, and having quit smoking were all significantly higher in the migrant pneumoconiosis group than in migrant workers with occupational but non-pulmonary diseases. The composition of migrant workers with pneumoconiosis was higher for someone smoking in the workplace and having a monthly income of less than ¥3000 than migrant workers with occupational but non-pulmonary diseases (table 1).

The 117 migrant workers with pneumoconiosis had no regular employer. They had spent an average of 14.54±9.16 years working in regions outside their household location. The duration of working outside was concentrated between 1 and 10 years (54 workers, 46.15%). Fifty-six workers (47.86%) reported changing employment more than twice, 25 workers (21.37%) had signed an employment contract, whereas 10 workers (8.55%) had medical insurance each. The longest duration of employment was 3.63±2.41 years, with 45 people (38.46%) working for 0–2 years and 27 people (23.08%) working for 2–4 years (table 2).

The composition ratios of dust exposure at 30–44 years of age and dust exposure for 1–10 years were greater in migrant workers with pneumoconiosis than in SOE workers with pneumoconiosis. There was no statistically significant difference in the composition of migrant workers with pneumoconiosis and migrant workers with occupational but non-pulmonary diseases in terms of age at morbidity and years of dust exposure. Migrant workers

with pneumoconiosis had a higher proportion of exposure to mineral and mixed dust than migrant workers with occupational but non-pulmonary diseases (table 3).

The mean age of morbidity of pneumoconiosis was 43.80±8.42 years in migrant workers, with the majority of cases occurring between the ages of 33 and 47 years (109, 55.05%). The mean age of morbidity in the SOE workers with pneumoconiosis was 46.3±8.75 years, with the majority of cases occurring between 48 and 62 years of age (95, 46.34%). The composition ratio of stage III was higher in migrant workers than in SOE workers with pneumoconiosis (table 4).

In comparison with SOE workers with pneumoconiosis, migrant workers with pneumoconiosis were mostly dry and worked more than 8 hours every day. For migrant workers with pneumoconiosis, the proportion of workplaces with no or just natural ventilation and no dust protection was greater than that of SOE workers with pneumoconiosis. The proportion of workplaces with more than 8 hours per day and no ventilation was higher in migrant workers with pneumoconiosis than in migrant workers with occupational but non-pulmonary diseases. All other labour protection measures, including dust management regulations, occupational health check-ups and education, and workplace dust testing, were worse for migrant workers with pneumoconiosis compared with the two control groups (table 5).

As independent variables, variables with statistically significant differences in the univariate between-group analysis of the migrant pneumoconiosis group and migrant workers with occupational but non-pulmonary diseases were included. After combining professional judgements (using a DAG), the multifactorial binary logistic regression analysis contained 15 variables in all:

**Table 5** Labour protection of migrant workers with pneumoconiosis compared with state-owned enterprise workers with pneumoconiosis, and state-owned enterprise workers and migrant workers with non-pulmonary occupational diseases

Variables N (%)	Migrant workers with pneumoconiosis n=198	State-owned enterprise workers with pneumoconiosis n=205	Migrant workers with non-pulmonary occupational diseases n=198
Method of operation			
Wet	26 (13.13)	53 (25.85)*	29 (14.65)
Dry	172 (86.87)	152 (74.15)	169 (85.35)
Average daily working hours			
≤8	100 (50.51)	159 (77.56)*	137 (69.19)†
>8	98 (49.49)	46 (22.44)	61 (30.81)
Mode of operation			
Mechanisation	108 (54.55)	146 (71.22)*	157 (79.29)†
Non-mechanical	90 (45.45)	59 (28.78)	41 (20.71)
Ventilation			
Both	8 (4.04)	24 (11.71)*	79 (39.90)†
Natural	74 (37.37)	55 (26.83)*	61 (30.81)
Mechanical	63 (31.82)	91 (44.39)*	47 (23.74)
None	53 (26.77)	35 (17.07)*	11 (5.56)†
Use of dust protection			
Yes	116 (58.59)	151 (73.66)*	128 (64.65)
No	82 (41.41)	54 (26.34)	70 (35.35)
Rules and regulations			
Unclear	17 (8.59)	34 (16.59)*	62 (31.31)†
Yes	19 (9.60)	107 (52.20)*	63 (31.82)†
No	162 (81.82)	64 (31.22)*	73 (36.87)†
Pre-employment medical examination			
Yes	63 (31.82)	183 (88.27)*	170 (85.86)†
No	135 (68.18)	22 (10.73)	28 (14.14)
Medical examination during in-service			
Yes	64 (32.32)	188 (91.71)*	174 (87.88)†
No	134 (67.68)	17 (8.29)	24 (12.12)
Post-employment medical examinations			
Yes	39 (19.70)	153 (74.63)*	174 (87.88)†
No	159 (80.30)	52 (25.37)	24 (12.12)
Occupational health education			
Unclear	4 (2.02)	9 (4.39)*	14 (7.07)†
Yes	29 (14.65)	164 (80.00)*	101 (51.01)†
No	165 (83.33)	32 (15.61)*	83 (41.92)†
Dust detection			
Unclear	25 (12.69)	69 (33.66)*	50 (25.25)†
Yes	19 (9.64)	75 (36.59)*	50 (25.25)†
No	153 (77.66)	61 (29.76)*	98 (49.49)†

\*Migrant workers with pneumoconiosis versus state-owned enterprise workers:  $p < 0.05/n$ , where n is the total number of Bonferroni correction tests.  
†Migrant workers with pneumoconiosis versus migrant workers with non-pulmonary occupational disease:  $p < 0.05/n$ , where n is the total number of Bonferroni correction tests.

gender, education, smoking, someone smoking in the workplace, regular sleeping hours per night, dust exposure, average daily working hours, mode of operation, ventilation, rules and regulations, medical examinations (before, during and after work), occupational health education and dust detection (online supplemental figure 1). An OR <1 indicates a protective factor, while an OR >1 indicates a risk factor. Due to the fact that one frequency in the cross-tabulation of dust exposure was

0, 0.5 was added to all cross-tabulation frequencies for dust exposure. The OR for dust exposure was estimated to be 499.25, with a 95% CI of 68.33 to 3647.59. Migrant workers with dust exposure and someone smoking in the workplace (OR=5.67, 95% CI: 2.18 to 14.78) were associated with an increased risk of pneumoconiosis. Sleeping regularly each night (OR=0.23, 95% CI: 0.09 to 0.60), ventilation by both natural and mechanical (OR=0.09, 95% CI: 0.01 to 0.65), having dust management rules and

**Table 6** Analysis of factors associated with the morbidity of migrant workers with pneumoconiosis

Variables	$\beta$	OR	95% CI
Dust exposure*			
No	Reference		
Yes	6.21	499.25	68.33 to 3647.59
Someone smoking in the workplace*			
No	Reference		
Yes	1.74	5.67	2.18 to 14.78
Regular sleeping hours per night*			
No	Reference		
Yes	-1.47	0.23	0.09 to 0.60
Ventilation			
None	Reference		
Both*	-2.37	0.09	0.01 to 0.65
Natural	-0.38	0.69	0.15 to 3.08
Mechanical	-0.17	0.84	0.19 to 3.76
Rules and regulations			
No	Reference		
Unclear	-1.83	0.16	0.01 to 4.34
Yes*	-1.52	0.22	0.07 to 0.66
Post-employment medical examination*			
No	Reference		
Yes	-1.42	0.24	0.09 to 0.63

\*P<0.05.

regulations (OR=0.22, 95% CI: 0.07 to 0.66), and having post-employment medical examinations (OR=0.24, 95% CI: 0.09 to 0.63) were associated with a decreased risk of pneumoconiosis (table 6).

## DISCUSSION

### Epidemiological characteristics of migrant workers with pneumoconiosis

The percentage of workers with a primary school education or less was higher in the migrant pneumoconiosis group than in the group of SOE workers with pneumoconiosis, which is similar to the findings of Gu's study.<sup>15</sup> Migrant workers with pneumoconiosis have a lower quality of life when they have a low educational attainment.<sup>16</sup> The average monthly income of migrant workers with pneumoconiosis was lower than that of SOE workers with pneumoconiosis. This has been proven to have an effect on the quality of life of migrant workers with pneumoconiosis, who have a worse quality of life than SOE workers with pneumoconiosis.<sup>17</sup> Almost 60% of migrant workers with pneumoconiosis lacked a stable employer. They had worked outside of their registered household location on average for almost 15 years, and nearly half of them had changed occupations more than twice a year. Our study discovered that inadequate employment

stability is a significant issue for migrant workers. This has a negative effect on not only productivity growth, but also the inclination of migrant workers to officially relocate.<sup>12 18</sup> To overcome this issue, migrant workers acquire work experience and continuously enhance their labour skills, and relevant authorities take a more active role in vocational skill training.<sup>19 20</sup>

The age of morbidity of pneumoconiosis among migrant workers is primarily between 33 and 47 years, that is, young adults, which is similar to the analysis of workers with silicosis in the UK over a 10-year period by Barber *et al.*<sup>21</sup> The analysis, by Zhao *et al.*, of new pneumoconiosis cases in Hebei Province between 2001 and 2015 similarly discovered a tendency toward younger pneumoconiosis.<sup>10</sup> Compared with SOE workers with pneumoconiosis, migrant workers start to be exposed to dust at an earlier age, which is of shorter duration but results in both morbidity and a higher proportion of tertiary pneumoconiosis at an earlier age. This differs from Yao *et al.*'s characterisation of pneumoconiosis among migrant and non-migrant workers<sup>22</sup> and may be explained by the significantly higher level of labour protection among SOE workers than migrant workers. For instance, this study discovered that ventilation, mechanisation and dust protection are much greater among SOE workers than among dust-exposed migrant workers. Effective labour protection resulted in decreased dust concentrations for workers exposed for the same period of time in dust-generating SOEs.

### Factors associated with the morbidity of pneumoconiosis in migrant workers

A history of dust exposure is a necessary diagnostic factor for pneumoconiosis. Studies have shown that the amount of dust exposure and the duration of dust exposure are factors associated with the morbidity of pneumoconiosis. Wen's cohort study on dust exposure workers discovered a high association between dust exposure and the morbidity of pneumoconiosis.<sup>11</sup> In a study of workers with silicosis in the Turkish ceramics industry, Karataş *et al.* showed that long working hours increased the risk of silicosis.<sup>9</sup> Our original version of the questionnaire investigated dust concentration exposure and dust dispersion, but these were removed in subsequent versions because the study participants did not remember or did not have dust detection during the presurvey. The content of these items could not be investigated by the questionnaire. Smoking and dust exposure together can have a detrimental effect on pulmonary function, with the interaction between dust exposure and smoking having a higher effect than either alone.<sup>23</sup> When someone smokes at work while experiencing dust exposure, the combined action causes both them and the surrounding dust-exposed migrant workers to inhale more dust, which becomes stuck in their lungs, increasing their risk of impaired lung ventilation function.

The irregular work schedules of migrant workers may be due to working double shifts, resulting in disruption

of their biological clocks. Sleep length and work shifts have been demonstrated to be strongly associated with the emergence of inadequate health among migrant workers.<sup>24 25</sup> Combining natural and mechanical ventilation, such as the use of long-pressure and short-extraction ventilation systems, efficiently reduces dust concentrations in workplaces for migrant workers and may be considered.<sup>26</sup> The majority of migrant workers with pneumoconiosis reported that their employers did not have dust rules and regulations. West *et al* found that the rate of asbestos-related diseases is lower for sheet metal workers who started work after the implementation of environmental and occupational regulations in the USA.<sup>8</sup> Appropriate dust rules and regulations can aid in the protection of the legal rights of migrant workers exposed to dust and those who contract pneumoconiosis. Few migrant workers have post-employment medical examinations. Pneumoconiosis has a latent period, and some migrant workers may still develop pneumoconiosis several years after leaving work, so attention should be paid to their post-employment medical examinations.<sup>27 28</sup>

In the past 5 years, there has been relatively little research on the factors associated with the morbidity of migrant workers with pneumoconiosis. This study may enrich the content. Our study chose representative hospitals from three cities and investigated many new cases and different stages of pneumoconiosis. However, this study has certain limitations. Due to the difficulty of contacting dust-exposed migrant workers who did not have pneumoconiosis, the actual study used migrant workers with non-pulmonary occupational diseases as a control group. This somewhat reduces the control group's comparability. The questionnaire included no mention of dust concentrations. Misclassification of exposures and outcomes may introduce bias into the study. Despite our best efforts to control for selection bias, it may not be possible to avoid it. The study collects data using a questionnaire, which is prone to bias due to self-reporting behaviour. One weakness of all cross-sectional studies is the possibility of unmeasured residual confounding. It is not known whether unmeasured residual confounders would change the factors associated with morbidity of migrant workers with pneumoconiosis.

In conclusion, compared with workers in SOE who had pneumoconiosis, migrant workers with pneumoconiosis are exposed to dust at an earlier age, acquire pneumoconiosis at an earlier age and have a higher proportion of tertiary pneumoconiosis. They are predominantly men, and have inadequate employment stability and medical insurance. Dust protection is rarely used, workplace ventilation is inadequate, and occupational health check-ups, dust monitoring, and management systems are inadequate.

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