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Research Article

Analysis of Pneumoconiosis Cases and Characteristics from 2004-2019 in Shandong Province

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Abstract

Pneumoconiosis is the most common occupational disease in the world; it is deadly but preventable. We aimed to evaluate the epidemiological trends and characteristics of pneumoconiosis in the large industrial Shandong Province of China to facilitate prevention and control measures. Data from 2004-2019 were extracted from an occupational disease reporting system regarding morbidity, regional distribution, industry distribution, types of pneumoconiosis, dust exposure duration, and age at diagnosis. A total of 15,853 pneumoconiosis cases were identified and classified as stage I (13,879 cases), stage II (1,402 cases), and stage III (572 cases). Yantai was the region with the most cases, which mainly involved cases of silicosis and coal workers' pneumoconiosis among individuals who were employed in mining and manufacturing industries. A high risk of pneumoconiosis was associated with rock drilling, road heading, and coal mixing. The average age at diagnosis was 52 years, and the average duration of dust exposure was 18 years. The incidence of pneumoconiosis in Shandong Province is still high, with clear concentrations in specific regions, industries, and types of work, which should be targeted for pneumoconiosis prevention and control measures. Industrial regulations and steps to control dust generation are needed to help reduce the incidence of pneumoconiosis.

Keywords: Coal, Gold, Mining, Occupational disease, Pneumoconiosis, Silicosis

Introduction

Pneumoconiosis is an occupational disease that is mainly caused by the preventable inhalation of dust into the respiratory tract. Unfortunately, this disease cannot be cured, and most patients die because of respiratory failure. Pneumoconiosis is the most common occupational disease throughout the world [1,2]. In China, it causes serious health effects creating economic burden on workers and the country as a whole [3]. Shandong Province is a large industrial province with approximately 1.29 million workers exposed to occupational hazards (approximately 25% of the 4.9 million workers) in approximately 49,500 complex enterprises (Shandong Provincial People's Government, 2017) [4]. Furthermore, Shandong Province is ranked among the top three Chinese regions for the cumulative number of new pneumoconiosis cases. This has recently inspired disputes and petitions regarding occupational diseases, creating hidden threats to social stability.

In 1956, the State Council in China commissioned a report regarding occupational diseases ("The worker casualties accident report procedure"), and a database was established for pneumoconiosis cases in 1997 [5]. In 2006, the China Center for Disease Control and Prevention established the national occupational disease and occupational health information monitoring system, and institutions in China that diagnose occupational disease use this system to report occupational disease cases. Each case is verified by county, city, province, and country to ensure data accuracy. The former Ministry of Health evaluated the occupational disease reporting system and its influence on the Chinese disease prevention and control information system; this evaluation prompted updates to the occupational disease reporting network and data management processes. Therefore, in this study, we evaluated data from the pneumoconiosis cases reported in Shandong Province from January 1st, 2004 to December 31st 2019 to provide data support to the government for the prevention, identification, and control of pneumoconiosis.

Methods

To manage Chinese occupational disease cases by networks, Ministry of Health required that all the confirmed occupational disease cases should be submitted by diagnosis institutions through Network Direct Report System of Occupational Diseases in 2006. We searched this Chinese National Disease Prevention and Control Information System to identify pneumoconiosis cases in Shandong Province from 2004-2019 (data from 2004 and 2005 were retrieved from a DOS-based system using dBASE software). Data were collected on annual distribution, regional distribution, industry distribution, job-specific distribution, duration of dust exposure, and age at diagnosis. Industries were classified according to the GB/t4754-2011 National Economic Industry Classification guidelines (National Bureau of Statistics, 2013) [6].

Statistical Analysis

All categorical variables are presented as frequency and percentages; continuous variables are presented as mean and standard deviation. Variables were compared using analysis of variance and the t test as appropriate, and all analyses were performed using IBM SPSS software (version 22; IBM Corp., Armonk, NY, USA).

Results

Overall Distribution

There are 13 types of pneumoconiosis in China (National Health Commission of the People's Republic of China, 2013) [7], and 12 types were reported in Shandong Province from 2004-2019 (mica pneumoconiosis was not reported). During the study period, we identified 15,853 new cases of pneumoconiosis, and these most commonly involved silicosis (9,367 cases, 59.09%) and coal workers' pneumoconiosis (4,586 cases, 28.93%) (Tables 1 and 2). Pneumoconiosis complicated with pulmonary tuberculosis was observed in 0.39% of cases. All pneumoconiosis cases were classified as stage I for 13,879 cases (87.55%, including 47 cases [0.34%] of pulmonary tuberculosis), stage II for 1,402 cases (8.84%, including 8 cases [0.57%] of pulmonary tuberculosis), and stage III for 572 cases (3.61%, including 7 cases [1.22%] of pulmonary tuberculosis). The incidence of tuberculosis increased significantly at the later pneumoconiosis stages (F=13.770, P=0.001). Silicosis was the most common type that was associated with pulmonary tuberculosis. During this period, a fluctuating increase could be seen in silicosis, and cases of coal workers were declining, while the number of welders' cases remained stable despite three obvious increases (Tables 1,2).

Table 1: New pneumoconiosis cases in Shandong Province from 2004-2019.

	Total cases (TB cases)	TB rate (%)	Stage I (TB acases)	TB rate (%)	Stage II (TB cases)	TB rate (%)	Stage III (TB cases)	TB rate (%)
Silicosis	9,367 (46)	0.49	8,029 (33)	0.41	880 (6)	0.68	458 (7)	1.53
Coal workers'	4,586 (12)	0.26	4,104 (10)	0.24	399 (2)	0.5	83 (0)	0
Welders'	735 (2)	0.27	705 (2)	0.28	30 (0)	0	0 (0)	0
Others a	1,165 (2)	0.17	1,041 (2)	0.19	82 (0)	0	31 (0)	0
Total	15,853 (62)	0.39	13,879 (47)	0.34	1,402 (8)	0.57	572 (7)	1.22

Note*: a Includes graphite pneumoconiosis, carbon black pneumoconiosis, asbestosis, talc pneumoconiosis, cement pneumoconiosis, mica pneumoconiosis, ceramic workers' pneumoconiosis, aluminum pneumoconiosis, foundry workers' pneumoconiosis, and other pneumoconiosis that can be diagnosed according to the clinical and pathological diagnostic criteria.

Table 2: Annual distribution of new pneumoconiosis cases in Shandong Province from 2004-2019.

Year	Silicosis (%)	Coal workers (%)	Welders (%)	Others a (%)	Total (%)
2004	305 (3.26)	266 (5.80)	30 (4.08)	16 (1.59)	617 (3.89)
2005	403 (4.30)	226 (4.93)	39 (5.31)	113 (11.21)	781 (4.93)
2006	422 (4.51)	245 (5.34)	12 (1.63)	54 (5.36)	733 (4.62)
2007	622 (6.64)	472 (10.29)	52 (7.07)	127 (12.60)	1,273 (8.03)
2008	464 (4.95)	231 (5.04)	33 (4.49)	120 (11.90)	848 (5.35)
2009	569 (6.07)	254 (5.54)	41 (5.58)	93 (9.23)	957 (6.04)

2010	414 (4.42)	183 (3.99)	32 (4.35)	59 (5.85)	688 (4.34)
2011	661 (7.06)	170 (3.71)	64 (8.71)	91 (9.03)	98 (0.62)
2012	533 (5.69)	217 (4.73)	49 (6.67)	71 (7.04)	870 (5.49)
2013	576 (6.15)	304 (6.63)	48 (6.53)	54 (0.55)	982 (7.74)
2014	589 (6.29)	337 (7.35)	72 (9.80)	77 (7.64)	1,075 (6.78)
2015	720 (7.69)	621 (13.54)	49 (6.67)	71 (7.04)	1,461 (9.22)
2016	824 (8.80)	491 (10.71)	38 (5.17)	62 (6.15)	1,415 (8.93)
2017	775 (8.27)	248 (5.41)	97 (13.20)	47 (4.66)	1,167 (7.36)
2018	834 (8.90)	182 (3.97)	41 (5.58)	92 (9.13)	1,103 (6.961)
2019	656 (7.00)	139 (3.03)	38 (5.17)	64 (6.34)	897 (5.66)
Total	9,367 (100.00)	4,586 (100.00)	735 (100.00)	1,008 (100.00)	15,853 (100.00)

Note*: [a] Includes graphite pneumoconiosis, carbon black pneumoconiosis, asbestosis, talc pneumoconiosis, cement pneumoconiosis, mica pneumoconiosis, ceramic workers' pneumoconiosis, aluminum pneumoconiosis, foundry workers' pneumoconiosis, and other pneumoconiosis that can be diagnosed according to the clinical and pathological diagnostic criteria.

Regional Distribution

A total of 74.16% of all new pneumoconiosis cases were observed in five regions (Table 3): Yantai (4,771 cases, 30.10%), Zibo (2,627 cases, 16.57%), Jinan (1,811 cases, 11.42%), Tai'an (1,441 cases, 9.09%), and Weifang (1,107 cases, 6.98%). A total of 79.52% of all silicosis cases were observed in Yantai (4,242 cases, 45.29%), Jinan (945 cases, 10.09%), Zibo (880 cases, 9.39%), Linyi (800 cases, 8.54%), and Heze (582 cases, 6.21%). A total of 87.85% of all coal workers' pneumoconiosis cases were observed in Zibo (1,519 cases, 33.12%), Tai'an (1,286 cases, 28.04%), Jinan (678 cases, 14.78%), Weifang (267 cases, 5.82%), and Jining (267 cases, 5.82%) (Table 3).

Table 3: Regional distribution of new pneumoconiosis cases in Shandong Province from 2004-2019.

	Silicosis (%)	Coal workers' (%)	Welders' (%)	Others a (%)	Total (%)
Jinan	945 (10.09)	678 (14.78)	100 (13.61)	88 (7.55)	1,811 (11.42)
Qingdao	267 (2.85)	1 (0.02)	60 (8.16)	325 (27.89)	653 (4.12)
Zibo	880 (9.39)	1,519 (33.12)	97 (13.20)	131 (11.24)	2,627 (16.57)
Zaozhuang	94 (1.00)	79 (1.72)	2 (0.27)	4 (0.34)	179 (1.13)
Dongying	46 (0.49)	1 (0.01)	4 (0.54)	4 (0.34)	55 (0.35)
Yantai	4,242 (45.29)	265 (5.78)	58 (7.89)	206 (17.68)	4,771 (30.10)
Weifang	412 (4.40)	267 (5.82)	218 (29.66)	210 (18.03)	1,107 (6.98)
Jining	209 (2.23)	267 (5.82)	7 (0.95)	12 (1.03)	495 (3.12)
Tai'an	68 (0.73)	1,286 (28.04)	34 (4.63)	53 (4.55)	1,441 (9.09)
Weihai	390 (4.16)	22 (0.48)	111 (15.10)	63 (5.41)	586 (3.70)
Rizhao	60 (0.64)	0 (0.00)	14 (1.90)	2 (0.17)	76 (0.48)
Laiwu	168 (1.79)	84 (1.83)	9 (1.22)	2 (0.17)	263 (1.66)
Linyi	800 (8.54)	79 (1.72)	4 (0.54)	15 (1.29)	898 (5.66)
Dezhou	32 (0.34)	17 (0.37)	6 (0.82)	36 (3.09)	91 (0.57)
Liaocheng	113 (1.21)	3 (0.07)	8 (1.09)	5 (0.43)	129 (0.81)
Binzhou	59 (0.63)	5 (0.11)	2 (0.27)	7 (0.60)	73 (0.46)
Heze	582 (6.21)	13 (0.28)	1 (0.14)	2 (0.17)	598 (3.77)
Total	9,367 (100.00)	4,586 (100.00)	735 (100.00)	1,165 (100.00)	15,853 (100.00)

Note*: [a] Includes graphite pneumoconiosis, carbon black pneumoconiosis, asbestosis, talc pneumoconiosis, cement pneumoconiosis, mica pneumoconiosis, ceramic workers' pneumoconiosis, aluminum pneumoconiosis, foundry workers' pneumoconiosis, and other pneumoconiosis that can be diagnosed according to the clinical and pathological diagnostic criteria.

Industry Distribution

A total of 97.98% of new cases were observed in three industries: mining (9,691 cases, 61.13%); manufacturing (3,291 cases, 20.76%); and organizations related to public management, social security, and social groups (2,550 cases, 16.09%). The main groups in the mining industry were coal mining and washing (5,229 cases, 32.98%), nonferrous metal mining and dressing (3,595 cases, 22.68%), and auxiliary mining activities (415 cases, 2.62%). The main groups in the manufacturing industry were related to nonmetallic mineral products (1,348 cases, 8.50%), general and special equipment manufacturing (983 cases, 6.20%), and ferrous metal smelting and rolling (296 cases, 1.88%).

Silicosis cases were most common in mining (5,312 cases, 56.71%); manufacturing (1,548 cases, 16.53%); and organizations related to public management, social security, and social groups (2,353 cases, 25.12%). The main groups in the manufacturing industry were nonmetallic mineral products (792 cases, 8.46%), general and special equipment manufacturing (275 cases, 2.94%), and ferrous metal smelting and processing (198 cases, 2.11%). Most pneumoconiosis cases were observed in the coal mining and washing industries (3,821 cases, 83.32%) (Table 4).

Table 4: Industry distribution of new pneumoconiosis cases in Shandong Province from 2004-2019.

Industry	Silicosis (%)	Coal workers' (%)	Welders' (%)	Others a (%)	Total (%)
Agriculture, forestry, animal husbandry, and fishery	3 (0.03)	1 (0.02)	0 (0.00)	0 (0.00)	4 (0.01)
Mining	5,312 (56.71)	4,086 (89.10)	30 (4.08)	263 (22.58)	9,691 (61.13)
Manufacturing	1,548 (16.53)	219 (4.78)	668 (90.88)	856 (73.48)	3,291 (20.76)
Electricity, heat, gas, and water production/ supply	31 (0.33)	38 (0.83)	15 (2.04)	13 (1.12)	100 (0.63)
Construction	60 (0.64)	9 (0.2.)	14 (1.90)	3 (0.26)	86 (0.54)
Wholesale and retail	10 (0.11)	8 (0.17)	2 (0.27)	6 (0.52)	26 (0.16)
Transportation, storage, and postal services	6 (0.06)	0 (0.00)	3 (0.41)	1 (0.09)	10 (0.06)
Real estate	2 (0.02)	0 (0.00)	1 (0.14)	0 (0)	3 (0.01)
Leasing and business services	22 (0.23)	36 (0.78)	1 (0.14)	6 (0.52)	65 (0.41)
Scientific research and technology services	11 (0.12)	0 (0.00)	0 (0.00)	1 (0.09)	12 (0.08)
Water conservancy, environment, and public facilities management	0 (0.00)	1 (0.02)	0 (0.00)	1 (0.09)	2 (0.01)
Residential services, repair, and other services	1 (0.01)	0 (0.00)	0 (0.00)	1 (0.10)	2 (0.01)
Education	5 (0.05)	0 (0.00)	1 (0.14)	0 (0.00)	6 (0.04)
Health and social work	3 (0.03)	2 (0.04)	0 (0.00)	0 (0.00)	5 (0.03)
Public administration, social security, and social groups	2,353 (25.12)	185 (4.61)	0 (0.00)	12 (1.03)	2,550 (16.09)
Total	9,367 (100.00)	4,586 (100.00)	735 (100.00)	1,165 (100.00)	15,853 (100.00)

Note*: [a] Includes graphite pneumoconiosis, carbon black pneumoconiosis, asbestosis, talc pneumoconiosis, cement pneumoconiosis, mica pneumoconiosis, ceramic workers' pneumoconiosis, aluminum pneumoconiosis, foundry workers' pneumoconiosis, and other pneumoconiosis that can be diagnosed according to the clinical and pathological diagnostic criteria.

Job-level Distribution

The mining industry had 77.75% of new pneumoconiosis cases, and the jobs with the highest incidences of pneumoconiosis were rock drilling (2,512 cases, 15.85%), pure heading (1,833 cases, 11.56%), main heading (1,741 cases, 10.98%), coal mine mixing (1,690 cases, 10.66%), and transportation work (1,420 cases, 8.96%). The jobs with the highest incidence of silicosis were rock drilling (2,495 cases, 26.64%), pure tunneling (1,456 cases, 15.54%), transportation (1,327 cases, 14.17%), main heading (1,207 cases, 12.90%), and other mine work (629 cases, 6.71%). The coal mining jobs with the highest incidences of pneumoconiosis were coal mixing work (1,618 cases, 35.28%), main coal mining (911 cases, 19.86%), pure coal mining (723 cases, 15.77%), main road heading (534 cases, 11.64%), and pure excavating (374 cases, 8.16%) (Table 5).

Table 5: Age at diagnosis and dust exposure according to job type.

	Total pneumoconiosis			Silicosis			Coal workers' pneumoconiosis		
	Cases (%)	Age at diagnosis (Mean ± SD)	Dust exposure (Mean ± SD)	Cases (%)	Age at diagnosis (Mean ± SD)	Dust exposure (Mean ± SD)	Cases (%)	Age at diagnosis (Mean ± SD)	Dust exposure (Mean ± SD)
Rock driller	2,512 (15.85)	56.34±11.46	12.49±9.40	2,495 (26.64)	56.36±9.42	12.50±9.52	15 (0.33)	52.60±13.006	11.13±6.14
Blaster	56 (0.35)	54.61±11.07	13.50±9.75	51 (0.54)	54.90±11.13	13.90±9.88	5 (0.11)	51.60±11.040	18.20±9.65
Pillar worker	102 (0.64)	49.39±7.95	21.54±6.94	101 (1.08)	49.46±7.96	21.63±6.91	1 (0.02)	43	12
Porter	1,420 (8.96)	49.21±9.80	20.44±8.02	1,327 (14.17)	48.61±8.97	22.22±7.89	87 (1.90)	58.20±10.08	22.93±9.46
Selecting miner	51 (0.32)	54.39±9.02	22.00±10.27	50 (0.53)	54.12±8.69	22.28±10.52	1 (0.02)	68	8
Pure road header	1,833 (11.56)	59.24±10.74	13.50±9.84	1,456 (15.54)	59.31±10.46	11.58±9.34	374 (8.16)	59.07±11.691	20.96±7.43
Main road header	1,741 (10.98)	57.46±10.66	17.68±10.35	1,207 (12.90)	57.14±10.16	15.11±9.71	534 (11.64)	59.19±11.67	23.50±7.88
Pure miner	745 (4.70)	51.84±10.07	18.95±8.28	22 (0.23)	51.14±9.51	17.23±9.88	723 (15.77)	51.87±10.09	19.00±8.22
Main miner	948 (5.98)	53.03±9.53	20.63±8.53	36 (0.38)	51.44±8.85	18.63±9.22	911 (19.86)	52.84±9.60	20.71±8.50
Coal mine mixer	1,690 (10.66)	56.30±11.31	21.59±8.52	72 (0.77)	57.56±12.18	22.20±8.38	1,618 (35.28)	56.24±11.26	21.56±8.53
Coal preparation worker	19 (0.12)	52.37±8.96	19.39±9.91	1 (0.01)	53	26	18 (0.39)	52.33±9.22	19.39±9.91
Breaker	269 (1.70)	50.61±9.44	18.35±9.29	263 (2.81)	50.58±9.27	18.35±9.32	1 (0.02)	54	16
Miner	181 (1.14)	52.52±9.76	19.44±9.94	159 (1.70)	51.93±11.53	19.45±10.63	19 (0.41)	57.89±11.01	20.26±8.41
Other mine workers a	758 (4.78)	53.11±9.83	23.19±8.53	629 (6.71)	51.90±9.37	22.66±8.62	123 (2.68)	59.23±10.79	26.03±7.83
Crusher	322 (2.03)	51.31±9.26	14.85±10.64	293 (3.13)	50.92±9.19	14.00±10.21	7 (0.15)	59.71±10.05	22.86±13.68
Transporter	124 (0.78)	51.21±8.28	19.68±9.59	77 (0.82)	51.19±9.09	19.83±8.98	42 (0.92)	50.41±10.60	18.16±9.28
Packer	47 (0.30)	49.00±7.65	17.00±9.53	22 (0.23)	48.23±6.43	16.55±9.46	1 (0.02)	54	8
Shaper	346 (2.18)	48.41±9.04	18.08±9.27	238 (2.54)	47.68±8.99	17.36±9.42	0 (0.00)	0	0
Loading kiln worker	49 (0.31)	50.85±9.62	20.76±8.01	36 (0.38)	49.24±8.69	19.76±9.58	1 (0.02)	53	30
Calciner	79 (0.50)	50.19±8.46	19.47±9.27	53 (0.57)	49.72±7.67	18.69±9.37	1 (0.02)	51	7
Stonecutter	14 (0.09)	67.14±12.14	21.64±9.48	12 (0.13)	69.75±10.52	23.92±7.82	1 (0.02)	52	11
Cement raw material worker	26 (0.16)	50.54±6.09	24.62±7.45	9 (0.10)	47.44±5.73	25.67±8.20	0 (0.00)	0	0
Cement maker	57 (0.40)	53.67±8.53	24.86±8.39	1 (0.01)	59	31	0 (0.00)	0	0
Dryer	8 (0.05)	54.63±12.05	16.38±13.32	2 (0.02)	50.00±16.97	3.50±0.71	1 (0.02)	42	25
Asbestos weaver	157 (1.00)	65.76±10.42	26.31±6.63	0 (0.00)	0	0	0 (0.00)	0	0

Asbestos worker	173 (1.09)	62.60±10.74	23.60±8.48	0 (0.00)	0	0	0 (0.00)	0	0
Molding sand worker	208 (1.30)	48.70±8.22	20.32±9.77	82 (0.88)	47.63±8.09	16.57±9.79	2 (0.04)	46.50±4.95	18.50±9.19
Sand remover	166 (1.05)	48.51±9.77	16.69±9.42	130 (1.39)	47.18±9.69	15.88±9.15	0 (0.00)	0	0
Smelting and casting	212 (1.34)	49.03±9.67	19.23±9.02	53 (0.57)	50.33±11.93	18.26±8.97	1 (0.02)	46	27
Electric welder	736 (4.64)	44.06±9.48	17.96±9.16	8 (0.09)	42.50±8.21	23.00±7.89	2 (0.04)	44.00±7.07	24.50±4.95
Furnace repairer and builder	65 (0.41)	51.98±8.65	24.25±10.17	31 (0.33)	52.07±8.02	26.74±10.46	19 (0.41)	50.00±7.98	21.47±9.42
Raw material worker	218 (1.38)	50.29±8.99	18.26±9.86	139 (1.48)	49.44±9.19	18.30±10.52	16 (0.34)	47.88±5.60	17.00±8.17
Other factory workers b	521 (3.29)	51.81±10.20	18.59±9.54	312 (3.33)	51.45±10.11	16.93±10.44	62 (1.35)	53.15±8.46	22.06±9.69
Total	15,853 (100.00)	54.08±11.11	17.86±9.92	9,367 (100.00)	54.15±10.86	15.7±10.09	4,586 (100.00)	55.33±11.00	21.24±8.56

Note*: [a] Other types of work in mines that were not listed. [b] Other types of work in factories that were not listed.

Note*: The names of the types of work are classified according to the Classification Catalogue of Work Types of the People's Republic of China (1992 edition).

Age at Diagnosis and Duration of Dust Exposure

During the study period, the average age at diagnosis of new pneumoconiosis was 52 years, and the average duration of dust exposure was 18 years (Tables 5 and 6). The mean age at diagnosis of pneumoconiosis (f=84.056, P=0.001) and the duration of dust exposure (f=74.298, P=0.001) exhibited significant between-group differences. The oldest age at diagnosis was 65 years (for asbestos pneumoconiosis) and 44 years (for welders' pneumoconiosis). The longest duration of dust exposure was 25 years for cement pneumoconiosis, and the shortest duration was 11 years for graphite pneumoconiosis. After statistical analysis, the results revealed significant differences between the new silicosis cases group and coal workers' pneumoconiosis case group for duration of dust exposure (t=-27.549, P=0.001) and age at diagnosis (t=-9.334, P<0.05). Furthermore, there were significant differences between rock drillers, pure road headers, coal mine mixing workers, main road headers, and transportation workers in terms of age at diagnosis (f=165.131, P=0.001) and duration of dust exposure (f=165.131, P=0.001) (Table 6).

Table 6: Age distribution of new pneumoconiosis cases in Shandong Province from 2004-2019.

Year of first dust exposure	Total pneumoconiosis			Silicosis			Coal workers' pneumoconiosis		
	Cases (%)	Age at diagnosis (Mean ± SD)	Dust exposure (Mean ± SD)	Cases (%)	Age at diagnosis (Mean ± SD)	Dust exposure (Mean ± SD)	Cases (%)	Age at diagnosis (Mean ± SD)	Dust exposure (Mean ± SD)
<1950	73 (0.46)	78.61±4.21	26.26±10.19	16 (0.17)	78.40±3.89	22.40±12.21	55 (1.20)	78.78±4.27	26.96±8.56
1950-1959	1,248 (7.87)	73.19±4.97	21.02±11.49	575 (6.14)	72.49±4.61	15.43±12.h34	482 (10.51)	72.76±5.21	26.11±7.73
1960-1969	1,752 (11.05)	67.18±5.50	13.51±11.42	1,256 (13.41)	67.23±4.95	9.1±9.49	368 (8.02)	67.64±5.80	24.56±7.55
1970-1979	3,740 (23.59)	57.76±6.12	20.60±11.54	2,303 (24.59)	58.14±6.27	17.21±11.96	1,069 (23.31)	58.19±6.67	25.94±6.83
1980-1989	3,490 (22.01)	49.04±6.32	23.24±5.93	1,900 (20.28)	48.7±6.20	22.10±6.31	1,152 (25.12)	49.56±6.39	24.11±5.13
1990-1999	2,968 (18.72)	45.02±6.92	16.88±5.19	1,951 (20.83)	43.91±6.72	17.13±4.45	642 (14.00)	46.47±6.69	16.36±4.60
2000-2009	2,211 (13.95)	47.05±6.83	9.7±3.25	1,103 (11.78)	47.44±6.99	9.58±3.55	771 (16.81)	47.64±5.57	9.35±2.63

2010-2019	161 (1.02)	48.11±6.55	3.36±1.58	263 (2.81)	48.06±6.78	4.32±2.08	47 (1.02)	48.81±5.32	4.32±2.08
Total	15,853 (100.00)	54.08±11.11	17.86±9.92	9,367 (100.00)	54.15±10.86	15.76±10.09	4,586 (100.00)	55.33±11.00	21.24±8.56

The earliest dust exposure was reported in 1935, and the latest dust exposure was reported in 2018. The first instance of dust exposure was reported during the 1970s-1990s for 64.33% of pneumoconiosis cases. The most common age at diagnosis was 45-55 years (45.90% of new cases), and 21.19% of new cases had an exposure duration<10 years.

Discussion

The Chinese government requires accurate and reliable data to support and assess the implementation and planning of occupational disease prevention and control policies. Related data can be obtained in three general ways: i) employers are legally required to report directly to health, labor, and social security administrative departments; ii) payments related to industrial injury compensation claims; and iii) physician-provided diagnostic information. Globally, less than one-half of all countries collect data on occupational diseases [8], and only a few countries systematically collect data regarding occupational disease (such as China, the United States, the United Kingdom, New Zealand, Germany, and Finland) [9]. China has various laws and regulations regarding occupational disease reporting, such as the 1988 Measures for Reporting Occupational Diseases [10], the Administrative Measures for the Diagnosis and Identification of Occupational Diseases (National Health Commission of the People's Republic of China, 2013) [11] and the Law of the People's Republic of China on the Prevention and Control of Occupational Diseases (National Health Commission of the People's Republic of China, 2013) [12]. These laws all require public health administrative departments at or above the county level to be responsible for the management of statistical reports regarding occupational diseases in their administrative regions, which are then aggregated by departments that are qualified for diagnosis regarding occupational disease. The National Health Commission of the People's Republic of China publishes annual incidences of occupational diseases. However, the data are very limited, and a multidepartment data sharing mechanism has been suggested at the national level. The reported data could be used by health administrative departments, labor and social security departments, occupational disease prevention and control institutions, and employers to set objectives for the prevention and control of occupational disease. These data could also be used for occupational disease health supervision, inspection, evaluation of prevention and control effect, and monitoring and early warning of occupational disease, which might help the early prevention, discovery, diagnosis, and treatment of occupational disease.

Shandong Province is the most economically and technologically developed province in northern China and has the third highest annual gross domestic product in China [13]. However, the underlying economic growth is linked to an increasing number of occupational diseases, which we observed in the present study, and these increases are consistent with increasing incidences that have been reported in China [3] Hunan [14], Guangdong [15], Jiangsu [16] and Zhejiang [17]. These increases might be related to the blind pursuit of economic interests, simple production of equipment, low awareness of occupational hazards, and poor compliance with related laws of the employers. In addition, there are limited systems for supervising and managing occupational health measures, which makes it difficult to implement protective measures. Additionally, occupational health supervision and management is not in place; therefore, it is difficult to implement protective measures. The increasing incidences of occupational diseases might also be partially related to some positive factors, such as the expansion of the definitions of occupational diseases, improvements in reporting systems and network construction, improvements in diagnoses, establishment of appraisal and compensation mechanisms of occupational diseases, improvements in the occupational prevention awareness of laborers of large-scale employers, and recovery from long-incubation-period pneumoconiosis.

This study revealed that approximately 1.22% of pneumoconiosis cases were complicated with pulmonary tuberculosis, which is lower than the 6.6% rate reported by *Xia, et al.* [18]. This may be related to the low positive rates of sputum smears or sputum cultures for Mycobacterium tuberculosis among pneumoconiosis patients [19], which complicates the diagnosis of pneumoconiosis with pulmonary tuberculosis. Nevertheless, tuberculosis is one of the direct causes of death among silicosis patients [20,21], and these patients are often highly resistant to antituberculosis treatment [19]. Thus, measures are needed to prevent and effectively treat pulmonary tuberculosis in this setting.

High incidences of new pneumoconiosis cases in Shandong Province were often observed in mining areas, such as in Yantai City, which has numerous gold mining and processing enterprises and had a high incidence of silicosis. In addition, coal mining enterprises are concentrated in Zibo City, Tai'an City, and Jinan City, which had high incidences of coal workers' pneumoconiosis. Qingdao City has numerous asbestos processing enterprises and a high incidence of asbestosis [22]. Thus, the distribution area and type of pneumoconiosis is related to the structure of the local industry, and governments should strengthen the supervision and management of large-scale gold mines, coal mines, and asbestos processing enterprises in areas with a high incidence of pneumoconiosis.

Shandong Province is an important gold-producing area in China-it houses the top seven gold mines in China and accounts for >25% of national gold production [23]. However, gold mining is associated with a high incidence of silicosis in China, which is related to the high concentration of free SiO_2 in dust produced during dry gold mining [24]. The present study revealed that rock drilling, road heading, and transportation work were high-risk jobs, i.e., laborers are exposed to high concentrations of free SiO_2, which is presumably related to the speed and severity of silicosis. Previous reports have also indicated that younger ages at diagnosis were associated with higher dust concentrations, longer working times, lower access to effective personal protective equipment, and other factors [3,25].

In China, Shandong Province produces the second largest volume of coal [26], and coal workers' pneumoconiosis was the second most common type of pneumoconiosis in this province. The occurrence and development of coal workers' pneumoconiosis is the result of many factors under certain conditions: dust type and concentration in the workplace, concentration of free SiO_2 in the dust, dust dispersion, duration of dust exposure, individual immune status, dust control measures, and other [27]. The vast majority of coal worker pneumoconiosis is distributed in the coal industry, and coal mine mixing and coal mining are high-risk jobs. Coal miners frequently come from rural areas, have limited education, do not receive vocational training, and work in areas with limited protective measures [28].

These results illustrate the importance of effective dust monitoring and mitigation efforts during gold and coal mining. Therefore, gold mine and coal mine enterprises should strengthen dust monitoring in tunnels and mining areas where high-risk jobs are located and take effective measures to reduce dust concentrations. It is also suggested that government departments should strengthen the management of gold mine and coal mine businesses, improve dust prevention and mitigation measures, and improve the working atmosphere. To reduce the incidence rate of silicosis and coal worker pneumoconiosis, we should increase the training of workers on occupation health protection. These steps may help improve the working environment and reduce the incidences of silicosis and coal workers' pneumoconiosis.

This study revealed that the average age at the diagnosis of silicosis was 53 years, and the average duration of dust exposure was 15 years. Among cases of coal workers' pneumoconiosis, the average age at diagnosis and the average duration of dust exposure were 53 and 22 years, respectively. Interestingly, 64.33% of pneumoconiosis cases had first dust exposure from the 1970s to the 1990s, and some cases were diagnosed after nearly 30 years of retirement. Thus, additional health checkups may be needed for retired mine workers. Furthermore, China has defined mandatory occupational health monitoring for workers in the Technical Specification for Occupational Health Surveillance (National Health and Health Commission of the People's Republic of China, 2014) [29] and Management Measures for Occupational Health Surveillance (National Health and Health Commission of the People's Republic of China, 2018) [30]. For example, employers must organize and pay for occupational health examinations that are conducted before hiring, while working, and after leaving a job. However, some employers, particularly small- and medium-sized employers, do not comply with these requirements, and the lack of effective supervision of these programs leads to a high proportion of cases that are diagnosed with stage II-III pneumoconiosis.

Some studies have shown that occupational disease reporting data reflect less than 7% of the actual incidence of occupational diseases [31], that is, more than 90% of the cases failed to appear in the occupational disease reporting database. The results of the current study only focus on the reported pneumoconiosis, which has certain limitations, and is not enough to fully reflect the burden of pneumoconiosis in Shandong Province.

Conclusion

Combined with the epidemiological characteristics of pneumoconiosis analyzed in this study, our findings suggest that the Chinese government should strengthen the supervision and management of occupational health measures, based on the characteristics and trends of pneumoconiosis being analyzed. Potential methods consist of clearly defining departments' responsibilities and leading an effective occupational disease prevention and control system. In particular, mining enterprises in areas with high incidences of pneumoconiosis should develop dust prevention/mitigation strategies, control the generation of dust from the source, strictly implement occupational health management systems, and strengthen the health monitoring of workers with significant dust exposure. It is fundamental to decrease dust concentration and workers' exposure level in the workplace [32]. Legal restraint can be considered on the enterprises. For example, one of the aims of the Pneumoconiosis Law of 1960 in Japan was to improve dust exposure management for workplace health [33,34]. Furthermore, workers who are at high risk of pneumoconiosis need to undergo training on occupational health policy and protection to improve their knowledge on the use of personal protection equipment. China requires a national occupational disease prevention and control plan to curb the increasing incidence of pneumoconiosis, which would allow it to actively respond to the ILO (International Labour Organization) / WHO (World Health Organization) International Plan for the elimination of silicosis [35] and contribute to the global elimination of silicosis. And different provinces need to explore suitable prevention and control models according to their own characteristics.

To conclude, the morbidity of pneumoconiosis in Shandong Province was still high. The centralized distribution of the pneumoconiosis cases could be seen in several regions, industries, and work types. Furthermore, the significant differences between duration of dust exposure and age at diagnosis were revealed in several work types. This study provides information about the characteristics and trends of pneumoconiosis of Shandong Province, and highlights the insights into the needs for effective pneumoconiosis prevention and control strategies of China. Considering pneumoconiosis remains a serious public health problem, especially in many developing countries [33,36-41,], this study can be referred to the studies on similar situation of occupational diseases of other countries.

List of Abbreviations: WHO: World Health Organization; ILO: International Labour Organization.

Declarations

Ethics Approval and Consent to Participate

Ethical clearance and approval were sought and granted from Shandong Academy of Occupational Health and Occupational Medicine (Approval for ethical review of biomedical research involving humans, 2019-05). Participation of subjects was voluntary and written consent was obtained from all participants prior to data collection.

Consent for Publication

Not applicable

Availability of Data and Material

The datasets generated and/or analyzed during the current study are available in the Monitoring Information System of Occupational diseases and Health hazards repository, *https://10.249.6.18:8881/cdc/login*.

Competing Interests

The authors declare that they have no competing interests. The sponsors had no role in the design, execution, interpretation, or writing of the study.

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Author's Contributions

Conceptualization, Yanqin Chen and Hua Shao; Formal analysis, Yanqin Chen, Bangyuan An, Yinghua Ma and Zhenzhen Fu; Funding acquisition, Hua Shao; Methodology, Yanqin Chen; Project administration, Yanqin Chen; Resources, Yanqin Chen; Software, Yanqin Chen; Supervision, Yanqin Chen; Validation, Yanqin Chen; Writing-original draft, Yanqin Chen and Bangyuan An; Writing-review & editing, Yanqin Chen and Bangyuan An.

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