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Analysis of Pneumoconiosis Occurrence Among Cement Factory Workers at PT. X in Medan

Muhammad Nasir Nasution[1], Amira Permatasari Tarigan[1,2], Nuryunita Nainggolan[3], Rina Amelia[4], Agus Dwi Susanto[5]

[1]*Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Sumatera Utara, 20115, Indonesia*
[3]*Occupational and Enviromental Division, Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Sumatera Utara, 20115, Indonesia*
[4]*Department of Community Medicine, Faculty of Medicine, Universitas Sumatera Utara, 20155, Indonesia*
[5]*Occupational and Enviromental Division, Department of Pulmonology and Respiratory Medicine, Faculty of Medicine, Universitas Indonesia, DKI Jakarta, 10430, Indonesia*
*Corresponding Author: amira@usu.ac.id

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ABSTRACT

Pneumoconiosis is one of the occupational diseases with an increasing risk in the current era of industrialization. Workers in cement industries, who are continuously exposed to cement dust, are at high risk of developing pneumoconiosis. Cement dust contains harmful components like silica and calcium, which can cause inflammation in the respiratory tract. This research aimed to identify the risk factors associated with the occurrence of pneumoconiosis among workers. This research used an analytic approach with a cross-sectional design. The sample consisted of 43 workers from PT. X cement factory in Medan, selected through consecutive sampling. Data were collected through interviews, questionnaires, physical examinations, and chest radiographs to assess respiratory symptoms. A significant relationship was found between respiratory symptoms and pneumoconiosis incidence. No significant relationship was found between individual factors (age, gender, education, smoking habits) and occupational factors (PPE use, work experience, work location, and respiratory symptoms) with pneumoconiosis incidences. Despite exposure to cement dust, occupational factors and smoking habits were not directly related to the disease occurrence. The study recommends further research with a larger sample size and detailed dust level measurements. In conclusion, Occupational factors and smoking habits did not show a significant relationship with the occurrence of pneumoconiosis among workers at PT. X cement factory in Medan. Despite exposure to cement dust, individual factors and occupational risk control through the use of PPE and other preventive measures need to be improved.

Keyword: Pneumoconiosis, Cement Factory Workers, Cement Dust, Risk Factor

ABSTRAK

Pneumokoniosis merupakan salah satu penyakit yang memiliki resiko yang meningkat di era industrialisasi saat ini. Pekerja di industri semen yang terus-menerus terpapar debu semen memiliki risiko tinggi mengalami pneumokoniosis. Debu semen mengandung komponen berbahaya seperti silika dan kalsium yang dapat menimbulkan peradangan pada saluran pernapasan. Penelitian ini bertujuan untuk mengidentifikasi faktor risiko yang berhubungan dengan kejadian pneumokoniosis pada pekerja. Penelitian ini menggunakan pendekatan analitik dengan desain potong lintang. Sampel penelitian terdiri dari 43 pekerja pabrik semen PT. X di Medan, yang dipilih melalui consecutive sampling. Data dikumpulkan melalui wawancara, kuesioner, pemeriksaan fisik, dan foto rontgen dada untuk menilai gejala pernapasan. Hasil penelitian menunjukkan adanya hubungan yang signifikan antara gejala pernapasan dengan kejadian pneumokoniosis. Namun, tidak ditemukan hubungan yang signifikan antara faktor individu (usia, jenis kelamin, tingkat pendidikan, kebiasaan merokok) maupun faktor pekerjaan (penggunaan APD, lama kerja, lokasi kerja, serta gejala pernapasan) dengan kejadian pneumokoniosis. Meskipun terdapat paparan debu semen, faktor pekerjaan dan kebiasaan merokok tidak berhubungan langsung dengan kejadian penyakit ini. Penelitian ini merekomendasikan penelitian lebih lanjut dengan jumlah sampel yang lebih besar serta pengukuran tingkat debu yang lebih rinci. Sebagai kesimpulan, faktor pekerjaan dan kebiasaan merokok tidak menunjukkan hubungan yang signifikan dengan kejadian pneumokoniosis pada pekerja di pabrik semen PT. X Medan. Walaupun terdapat paparan debu semen, faktor individu dan pengendalian risiko kerja melalui penggunaan APD serta upaya pencegahan lainnya tetap perlu ditingkatkan.

Keyword: Pneumokoniosis, Pekerja pabrik semen, debu semen, faktor resiko

1. Introduction

Pneumoconiosis is one of interstitial lung diseases caused by exposure to dust particles that damage the lungs. Pneumoconiosis can arise from various types of dust exposure, such as exposure to coal dust, cotton dust and also inhaled dust from silica and asbestos.[1,2,3] In 2018 and 2020, new cases of occupational pneumoconiosis accounted for more than 80% of all new work-related disorders in China. The Global Burden of Disease (2019) showed an estimated 10200.8 (95% CI: 8049.62–13567.42) pneumoconiosis-related deaths in China, indicating the emergence of pneumoconiosis as a significant public health problem in China.[4,5]

In current era of industrialization, development is increasing rapidly. The increasing development process also increases the risk of occupational lung disease, where pneumoconiosis is one of the occupational lung diseases.[2] Cement is one of the most important materials in infrastructure development and is a key factor for economic growth. Cement is derived from hydrated calcium silicate, iron, magnesium and aluminium oxides, calcium sulfate and clay. Cement is not only an industrial pollutant but also an environmental contaminant especially near cement factories due to improper technology. Previous studies reported that exposure to cement dust may increase the risk of respiratory disorders and pneumoconiosis among cement factory workers.[6,7]

Cement dust exposure has been recognized as an important occupational health hazard associated with respiratory disorders and pneumoconiosis among cement factory workers. Although previous studies have identified cement dust as a risk factor for pneumoconiosis, limited studies have evaluated the association between individual and occupational factors, such as smoking habits, PPE use, work experience, and work location, among cement factory workers in Indonesia. Therefore, this study aimed to analyze factors associated with pneumoconiosis incidence among cement factory workers.

2. Methods

2.1. Study design and ethical approval

This study was an analytic observational study with a cross-sectional design conducted among cement factory workers at PT. X in Medan, North Sumatra, Indonesia. Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine, Universitas Sumatera Utara (Approval No. 1414/KEPK/USU/2024).

2.2. Study population and sampling

The study was conducted from December 2024 to January 2025. The study population consisted of cement factory workers at PT. X who fulfilled the inclusion and exclusion criteria. This study used a total sampling technique with a cross-sectional approach, resulting in a total sample of 43 workers. Subjects included workers aged >21 years who worked as cement processors at PT. X cement factory in Medan and agreed to participate by signing informed consent forms. Data collected included age, gender, educational level, body mass index (BMI), smoking habits, use of personal protective equipment (PPE), years of working, work location, respiratory symptoms, and work duration.

2.3. Inclusion and exclusion criteria

Inclusion criteria were: (1) subjects who worked as cement processors at PT. X cement factory in Medan city and (2) subjects aged >21 years. Subjects who had worked for less than one year were excluded because pneumoconiosis generally develops after prolonged occupational dust exposure.

2.4. Data collection

Data were collected through interviews using structured questionnaires, physical examinations, and chest radiographs. Interviews and questionnaires were used to obtain demographic characteristics, smoking habits, PPE use, work history, work location, work duration, and respiratory symptoms. Chest radiographs were performed to assess the presence of pneumoconiosis.

2.5. Statistical analysis and software

All collected data were processed and analyzed using SPSS software version 25. Descriptive analysis was performed to determine the frequency distribution of respondents' characteristics.

3. Results and Discussion

This research involved 43 respondents, of whom 3 (6.98%) had pneumoconiosis and 40 (93.02%) did not. All respondents with pneumoconiosis were male, had a history of smoking and were directly exposed to cement dust at work with a working duration of more than 40 hours per week.

Table 1. Sample Distribution

Characteristics	Frequency	
	Pneumoconiosis (%)	Without pneumoconiosis (%)
Age (years old)		
• ≤40 years	2 (4,7)	34 (79,1)
• > 40 years	1 (2,3)	6 (14)
Gender		
Male	3 (7,0)	40 (93,0)
Education		
• Bachelor degree	0 (0)	11 (25,6)
• Non-bachelor degree	3 (7,0)	29 (67,4)
BMI		
• ≤ 25	1 (2,3)	25 (58,1)
• > 25	2 (4,7)	15 (34,9)
Smoking habits		
• No	0 (0)	18 (41,9)
• Yes	3 (7,0)	22 (51,2)
Use of PPE		
• No	0 (0)	4 (9,3)
• Other than 3M mask	1 (2,3)	18 (41,9)
• 3M mask	2 (4,7)	18 (41,9)
Years of working		
• < 5	1 (2,3)	10 (23,3)
• ≥ 5	2 (4,7)	30 (69,8)
Work Location		
• No Exposure	0 (0)	7 (16,3)
• Direct Exposure	3 (7,0)	33 (76,7)
Work Duration		
• < 40 hours per weeks	0 (0)	3 (7,0)
• ≥ 40 hours per weeks	3 (7,0)	37 (86,0)

Analysis of the association between age and pneumoconiosis incidence showed that among 43 workers, the majority were aged ≤40 years (36 workers; 83.7%). Fisher's Exact test showed no significant association between age and pneumoconiosis incidence ($p = 0.421$). The strength of the association measured using Cramer's V indicated a weak association between the variables (Cramer's V = 0.407).

There were only 3 workers with education other than Strata who were recorded as diagnosed with pneumoconiosis. There was no significant association between Pneumoconiosis and Education in this data, as evidenced by the results of the Fisher's Exact Test and Cramer's V which showed a p value > 0.05.

Table 2. Statistical tests evaluated association between pneumoconiosis and patient characteristics.

Patient Characteristics		Pneumoconiosis		Total	P value
		Negative	Positive		
Age (years old)	≤ 40 years	34	2	36	0.421*
	> 40 years	6	1	7	
Total		40	3	43	0.407**
Education	Bachelor degree	11	0	11	0.558*
	Non-bachelor degree	29	3	32	
Total		40	3	43	0.292**
BMI (kg/m^2)	≤ 25	25	1	26	0.342*
	> 25	15	2	17	
Total		40	3	43	0.319**
Smoking habits	No	18	0	18	0.186*
	Yes	22	3	25	
Total		40	3	43	0.128**

*Fisher Exact
**Cramer's V

Fisher's Exact test showed no statistically significant association between BMI (p = 0.342) and smoking habits (p = 0.186) with pneumoconiosis incidence. The strength of association measured using Cramer's V indicated weak associations between BMI (Cramer's V = 0.319) and smoking habits (Cramer's V = 0.128) with pneumoconiosis incidence.

Table 3. Statistical tests evaluated correlation between pneumoconiosis and patient work characteristics

Work Characteristics		Pneumoconiosis		Total	P value
		Negative	Positive		
Use of PPE	No	4	0	4	1.000*
	Other than 3M Mask	18	1	19	
	3M Mask	18	2	20	
Total		40	3	43	0.716**
Years of working	< 5	10	1	11	0.598*
	≥ 5	30	2	32	
Total		40	3	43	0.750**
Work Exposure	No Exposure	7	0	7	0.579*
	Direct Exposure	33	3	36	
Total		40	3	43	0.428**
Work duration	< 40 hours	3	0	3	0.801*
	≥ 40 hours	37	3	40	
Total		40	3	43	0.623**

However, it was shown that pneumoconiosis was slightly more common among workers using 3M Masks, which may indicate that despite using masks, other factors may still contribute to the likelihood of pneumoconiosis incidences. There was no significant correlation between pneumoconiosis and the use of PPE in terms of the use of certain masks in this data, as evidenced by Fisher-Exact and Cramer's V tests results which showed a p value > 0.05.

Pneumoconiosis was more commonly found among workers with ≥5 years of working experience, suggesting that longer working duration may increase the risk of developing pneumoconiosis. However, Fisher's Exact test showed no statistically significant association between years of working and pneumoconiosis incidence (p > 0.05). The strength of association measured using Cramer's V indicated a weak association between the variables.

Proven pneumoconiosis was more prevalent in the exposed category, with 3 individuals recorded as having a diagnosis of pneumoconiosis. Although the numbers are small, exposure does appear to be associated with an increase in pneumoconiosis incidences. There was no significant correlation between Pneumoconiosis and work location in these data, as evidenced by Fisher-Exact and Cramer's V tests results which showed a p value > 0.05.

The statistical test results found p-value of 0.801 for the correlation between Pneumoconiosis and work duration, which indicates that there is no significant correlation between those variables. This means that the presence of Pneumoconiosis does not affect a person's work duration. In addition, the p-value using the Fisher-Exact Test and Cramer's V (0.623) indicates that the correlation between these variables is very weak, with the conclusion that there is no strong correlation between the two variables.

Table 4. Association between pneumoconiosis incidence and respiratory symptoms.

Pneumoconiosis	Symptoms (+)	Symptoms (-)	p-Value
	Dyspnea		
Negative	36	4	0.316*
Positive	3	1	
Total	38	5	0.224**
	Cough with phlegm		
Negative	35	5	0.005*
Positive	0	3	
Total	35	8	<0.001**
	Cough		
Negative	35	5	0.005*
Positive	0	3	
Total	35	8	<0.001**
	Dyspnea on the Morning		
Negative	38	2	1.000*
Positive	3	0	
Total	41	2	0.692**

*Fisher-Exact
**Cramer’s V

Among the respiratory symptoms evaluated in this study, cough and productive cough were more frequently observed among workers with pneumoconiosis. Fisher’s Exact test showed statistically significant associations between pneumoconiosis incidence and cough with phlegm (p = 0.005), as well as general cough symptoms (p = 0.005). The strength of association measured using Cramer’s V indicated strong associations between these respiratory symptoms and pneumoconiosis incidence. These findings suggest that chronic cough and productive cough may serve as important early clinical indicators of pneumoconiosis among cement factory workers.

In contrast, no statistically significant association was found between pneumoconiosis incidence and shortness of breath or morning dyspnea. The strength of association measured using Cramer’s V also indicated weak associations between these symptoms and pneumoconiosis incidence. This finding may indicate that dyspnea tends to appear in more advanced stages of respiratory impairment, whereas cough-related symptoms may occur earlier during disease progression.

DISCUSSION

Pneumoconiosis and age

In this study, no significant association was found between age and pneumoconiosis incidence among cement factory workers. Although most pneumoconiosis cases were observed among workers aged >40 years, cases were also identified in younger workers. This finding suggests that occupational exposure factors, such as duration and intensity of cement dust exposure, may have a greater influence on pneumoconiosis development than age alone. These findings emphasize the importance of occupational health surveillance and dust exposure control across all age groups in cement factory workers.[3,4]

The absence of a significant association between age and pneumoconiosis incidence may also be influenced by differences in work duration, exposure intensity, and compliance with personal protective equipment (PPE) use among workers. Previous studies have reported that younger workers may still experience substantial dust exposure if they begin working in high-risk environments at an early age.[5,6] In addition, occupational safety measures, including PPE use, workplace ventilation, and health education, may reduce the effect of age as an independent risk factor for pneumoconiosis.[7]

Although increasing age may contribute to declining lung function and reduced clearance of inhaled dust particles, this study suggests that occupational exposure remains the more dominant factor associated with pneumoconiosis among cement factory workers.[8,9]

Pneumoconiosis and Gender

According to the literature, pneumoconiosis is more often found in men because in general they work more in industrial sectors that have a high risk of exposure to inorganic dust, such as mining, construction, and manufacturing.[10] Therefore, the limitations on gender variation in the sample may reflect the representation of a particular working population, but also limit the ability to analyze the correlation between gender and disease. Some literature suggests that gender is not a direct risk factor for pneumoconiosis, but rather an indirect factor through differences in occupational types and exposure to the work environment.[2] On the other hand, the theory that there are biological differences between men and women in the lung response to particle exposure is still debated. Some studies suggest that women may have different susceptibility to toxic particles due to anatomical and hormonal differences, but this evidence is not consistent enough to draw any definite conclusions.[11] Thus, the absence of comparative data in this research not only limits statistical analysis but also hinders the overall interpretation of the role of gender in pneumoconiosis incidence.

Pneumoconiosis and Education

In general, educational attainment plays an important role in shaping knowledge, awareness, and preventive compliance related to occupational health, including the use of personal protective equipment (PPE). Evidence from studies conducted in China and India demonstrated that lower education levels are associated with increased susceptibility to occupational pulmonary risks and higher accident rates. Conversely, a negative correlation has been observed between education level and the occurrence of pneumoconiosis in workers, suggesting that higher education may facilitate better adherence to dust control measures, including proper use of respiratory protection, or enable transition to lower-exposure occupations. [12]

However, the findings of this research support other studies, which state that exposure to pneumoconiosis-causing agents is more related to work conditions than formal educational background.[13] Therefore, although in theory education can play a role in preventing occupational diseases, in practice factors such as type of work, duration of exposure, compliance with occupational safety, and industrial supervision have a more dominant role in influencing pneumoconiosis incidence.[14]

Pneumoconiosis and BMI

Pneumoconiosis is a lung disease caused by the accumulation of inorganic dust particles in the lung tissue, which is more influenced by the duration and intensity of exposure than nutritional status or body mass index.[15] Another study showed that although nutritional status can affect the body's immune and inflammatory responses, it is not a major factor in the pathogenesis of pneumoconiosis. In addition, nutritional status can be influenced by many external factors such as diet, lifestyle, and comorbidities, which are not directly related to the risk of dust exposure in the workplace.[7]

Although some theories suggest that obesity may worsen lung dysfunction due to restrictive mechanisms resulting from fat accumulation in the thoracic and abdominal walls, this is more relevant in the context of diseases such as asthma or chronic obstructive pulmonary disease (COPD), not pneumoconiosis.[16]

Other studies suggest that the effects of obesity on the lungs are mechanical and do not directly affect the inflammatory process caused by inorganic particles.[17] On the other hand, there is also an argument that malnutrition can accelerate the progression of chronic lung disease due to a weakened immune system, but this theory has not been consistently proven in the case of pneumoconiosis.[18] Thus, nutritional status, especially based on BMI categories, has not been proven to be a factor that has a significant correlation to pneumoconiosis incidence in the context of these data or the existing literature.

Pneumoconiosis and Smoking Habits

Smoking, although a major risk factor for chronic obstructive pulmonary disease (COPD) and lung cancer, does not directly cause pneumoconiosis.[19] Another study stated that smoking does not increase the accumulation of inorganic particles in the lungs but can worsen clinical symptoms and accelerate the decline in lung function in patients who have been chronically exposed to dust.[20] On the other hand, there is a theory that smoking can amplify the toxic effects of dust exposure by increasing oxidative stress and inflammation in the airways, which has the potential to accelerate the progression of lung fibrosis in patients with pneumoconiosis.[7] This is supported by other studies that show a synergistic interaction between dust exposure and cigarette smoke on impaired lung function. However, counterarguments suggest that smoking may also cause mucociliary changes that inhibit dust particle deposition in the alveoli, thereby theoretically reducing particle accumulation although this has not been strongly demonstrated clinically.[21] Therefore, although active smokers were more frequently found in pneumoconiosis cases in these data, the lack of a statistically significant association suggests that smoking is not a major independent factor in the etiology of pneumoconiosis, but rather a comorbid factor or clinical modifier.[19]

Pneumoconiosis and Use of PPE

Although descriptively, cases of pneumoconiosis were more common in users of 3M masks, this is not strong enough to conclude a causal correlation. This lack of correlation can be caused by various factors, such as inappropriate use of masks (eg, inconsistent use, selection of mask types that do not match the type of exposure, or errors in installation), as well as the potential for high exposure that cannot be fully overcome with masks alone.[2] According to the Occupational Safety and Health Administration (OSHA), the effectiveness of PPE is highly dependent on the suitability of the type and method of use, as well as adequate training for workers. Standard masks such as N95 or 3M masks are only effective if used correctly and in controlled environmental conditions.[22] Theoretically, the use of PPE, especially standard respirators such as N95 or P100 masks, has been shown to reduce the risk of inhalation of hazardous particles in dusty work environments.[23] Other studies have shown that correct respirator use significantly reduces the risk of work-related lung disorders. However, some studies have also suggested that the effectiveness of masks may be reduced if used for a long time without replacement, in environments with very high dust concentrations, or without proper training in their use.[23] On the other hand, there is also an argument that workers who wear masks tend to already be in high exposure work environments, so the risk may still be greater even when using PPE. Therefore, although in theory PPE protects against exposure to dust that causes pneumoconiosis, in practice a comprehensive approach is still needed, such as technical control of the work environment and education on the use of PPE for optimal prevention effectiveness.[25]

Pneumoconiosis and Working Duration

Although descriptively positive cases of pneumoconiosis are more often found in workers with a work period of $\geq$ 5 years, this is not yet statistically strong enough. This lack of correlation may be caused by other factors that are more dominant in influencing risk, such as dust concentration in the work environment, the type of material inhaled, and the effectiveness of dust protection and control systems.[26] According to another study, the risk of pneumoconiosis is determined by the cumulative dose of exposure, which is the result of the interaction between the intensity and duration of exposure. Therefore, someone with a long work period but with a low level of exposure or good use of PPE may have a lower risk than an individual with a short work period but in a highly polluted work environment.[2] Theoretically, longer work periods are often considered as an indicator of increasing accumulation of exposure to respirable dust, so that it should increase the risk of pneumoconiosis.[14] Another study showed a correlation between work periods of $\geq$ 10 years in the mining industry and an increased prevalence of pneumoconiosis. However, this theory has been criticized by some researchers who emphasize that tenure is not the only important variable—factors such as workplace ventilation, use of PPE, and frequency of job rotation also play a role in determining actual exposure levels.[2] In addition, individual variation in sensitivity to dust particles may also influence disease development. Therefore, although long tenure theoretically increases risk, the lack of a significant association in these data suggests the importance of considering more complex, multifactorial exposure factors in determining pneumoconiosis incidences.[14]

Pneumoconiosis and Working Location

The research results showed no significant correlation between work environment exposure (exposed or not exposed) and pneumoconiosis incidence, as evidenced by the Fisher Exact and Cramer's V tests with p-values > 0.05. This lack of correlation can be caused by several factors, one of which is the variation in the intensity and type of dust exposure between individuals included in the exposed category.[27] According to literature from the International Labor Organization (ILO), not all work environments with dust exposure have the same potential to cause pneumoconiosis - factors such as particle type (eg crystalline silica vs organic dust), duration of exposure, and the effectiveness of ventilation and engineering controls greatly affect the risk of disease. [2] Thus, the classification of exposure categories in this research may be too general and inadequate to describe the actual exposure burden that contributes to the pathogenesis of pneumoconiosis. In theory, prolonged and intense exposure to inorganic dust is a major risk factor for pneumoconiosis, as confirmed by studies that have been conducted in the coal mining industry.[28] However, several studies also state that not all exposed workers will develop the disease, due to protective factors such as consistent use of personal protective equipment, as well as individual genetic differences in responding to inhaled foreign particles.[29] On the other hand, counter theories also show that the existence of dust control programs and good occupational health surveillance can reduce the incidence of pneumoconiosis despite exposure. This supports the view that exposure alone is not enough as a single indicator in assessing the risk of pneumoconiosis—a multifactorial approach involving engineering, administrative, and work behavior controls is needed to comprehensively assess and reduce risk.[25]

Pneumoconiosis and Respiratory Symptoms

This study found that productive cough was significantly associated with pneumoconiosis, whereas shortness of breath was not. These findings suggest that productive cough may represent an earlier respiratory manifestation of chronic inorganic dust exposure in the studied workers. Chronic dust inhalation can cause airway irritation and mucus hypersecretion, leading to persistent productive cough.[10,30] In contrast, shortness of breath may not appear in all workers with pneumoconiosis because dyspnea is generally associated with more advanced impairment of pulmonary function.[31] In this study, the absence of a significant association between dyspnea and pneumoconiosis may indicate that some subjects were still in mild or early stages of disease. In addition, dyspnea is a nonspecific symptom that may also be influenced by smoking habits, previous respiratory disease, cardiovascular conditions, or other comorbidities.[30,32] This may explain why shortness of breath was reported by subjects both with and without pneumoconiosis. An important finding of this study is that productive cough may serve as a potential early clinical indicator in workers exposed to inorganic dust. This finding may support occupational health surveillance and early screening strategies, particularly in settings with limited access to radiological examinations. [33,34] However, this study has several limitations. The cross-sectional design limits causal interpretation between respiratory symptoms and pneumoconiosis. In addition, potential confounding factors such as smoking status, duration of exposure, and previous lung disease were not fully controlled, which may increase the risk of bias. Respiratory symptoms were also self-reported and may be subject to reporting bias.

4. Conclusion

This study found a significant association between cough, productive cough, and pneumoconiosis among cement factory workers at PT. X in Medan. In contrast, no significant associations were found between pneumoconiosis and age, educational level, BMI, smoking habits, use of PPE, years of working, work exposure, or work duration. These findings suggest that respiratory symptoms, particularly cough with phlegm, were more frequently observed among workers with pneumoconiosis in this study population. However, due to the cross-sectional design and the absence of multivariable analysis, causal relationships and independent risk factors could not be determined. Further studies with larger sample sizes and better control of potential confounding factors are needed to clarify these associations.

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Abbreviations

BMI	Body Mass Index
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment

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