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Risk factors of Coal Worker's Pneumoconiosis (CWP): A systematic review

Guspianto[1*], Budi Aswin[2], Nur Juninda Dewi[3]
[1,2,3] Study Program of Public Health Science, Universitas Jambi, Indonesia
*Corresponding author's email: guspianto@unja.ac.id

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Abstract

Background: Coal worker's pneumoconiosis (CWP) is a parenchymal lung disease caused by inhalation of dust from coal mines. In global, the prevalence of CWP was 18.8% in 2013, while in Indonesia the data was still scarce, despite having many coal mines. This was still be most important occupational disease issue in Indonesia. This study aims to obtain an overview of the risk factors for CWP including dust, length of exposure, susceptibility, and smoke through a systematic review.
Method: Search articles using four databases namely Google Scholar, Scopus, PubMed, and ScienceDirect using the PRISMA method using keywords "coal worker's pneumoconiosis" or "black lung" and "dust" and "long exposure" and "susceptibility" and "smoking. 14 articles that met the inclusion criteria were selected from 1,195 articles in the initial.
Results: A review of articles showed that the factor of dust, length of exposure, and individual susceptibility proved to be risk factors that influence and develop CWP, while smoking was not associated with the incidence of CWP, but could interfere with lung function.
Conclusion: It is recommended that coal mining workers always use personal protective equipment (PPE), especially respiratory protective equipment, maintain body stamina with adequate nutritional intake and rest, regular health checks, and do not smoke.

Keywords: CWP; dust; long exposure; susceptibility; smoking

INTRODUCTION

Pneumoconiosis is the most common restrictive lung disease suffered by workers, especially in developing countries, around 30% to 50%(1),(2). Pneumoconiosis is a disorder that occurs due to the accumulation of dust in the lungs which causes a tissue reaction to the dust characterized by complaints of shortness of breath and coughing(3). One type of pneumoconiosis in the coal mining industry is coal workers' pneumoconiosis (CWP). A study by Simanjuntak, et al (2015) found that 64.3% of coal mining workers experienced CWP on chest X-ray images(4). Research by Ulfahimayati, et al in 2020 found that 13.3% of coal mining company workers in Sawahlunto City experienced CWP(5). CWP is a preventable lung disease but can be complicated by respiratory failure and even death(6). Until now, no effective treatment has been found for CWP sufferers, and even severe sufferers sometimes require a lung transplant (7).

Increased dust exposure is known to have a positive effect on the incidence of CWP(8). Coal mine dust is a complex and heterogeneous mixture containing more than 50 different elements including carbon, crystalline silica, boron, cadmium, nickel, iron, antimony, lead, zinc, and many other elements(9). Many studies show dust levels as the main factor causing CWP, but several other factors are also known to be related to and influence CWP such as duration of exposure, body susceptibility, and smoking habits.

Worker tenure is a risk factor for CWP because it is related to the level of dust exposure(10). The working period determines how often and for how long workers are exposed to dust in the work environment. A study by Wu, et al (2019) proved that workers with exposure > 20 years had lung radiographic results indicating CWP 1.7 times (CI95%: 1.33 - 2.17) higher than workers with exposure < 10 years(11).

Individual vulnerability factors also play a role in the development of workers' illnesses, because occupational diseases are abnormal conditions caused by individual susceptibility to work environmental factors (12). Individual smoking habits and duration of worker dust exposure negatively impact lung function(13). A study by Qian, et al (2016) shows a dose-response relationship between smoking and decreased lung function such as forced expiratory volume (FEV) and forced expiratory flow (FEF)(14). This study aims to obtain a further description of the risk factors for pneumoconiosis in coal mine workers (CWP) including dust, exposure time, susceptibility, and smoking through a systematic study based on relevant literature findings.

METHOD

The research design is a systematic review with meta-synthesis (qualitative) of previous primary study articles. Search for articles on four databases, namely Google Scholar, Scopus, PubMed, and ScienceDirect which are accessed using Harzing's Publish or Perish. with the keywords "coal worker's pneumoconiosis" or "black lung" and "dust" and "long exposure" and "susceptibility" and "smoking".

Selection of articles according to the systematic review methodology follows the following steps: 1) Screening to see multiple articles and suitability of theme and abstract title, 2) Eligibility by assessing the suitability of the complete article with the desired criteria. Inclusion criteria are 1) theme according to research objectives; 2) publications in the last 10 years; 3) can be accessed in full (full text), and; 4) speak English, while the exclusion criteria are 1) the article is only an abstract; 2) not indexed, 3) not open access. Of the 1,195 articles in the initial study search, only 14 articles met all inclusion criteria (see Figure 1).

Analysis and interpretation were carried out by discussing the literature findings descriptively according to the research objective, namely to look at the risk factors for CWP consisting of dust, exposure time, susceptibility, and smoking. This research uses a search method following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) strategy(15), with research questions referring to the PICO Framework (Problem-Intervention-Comparison-Outcome).

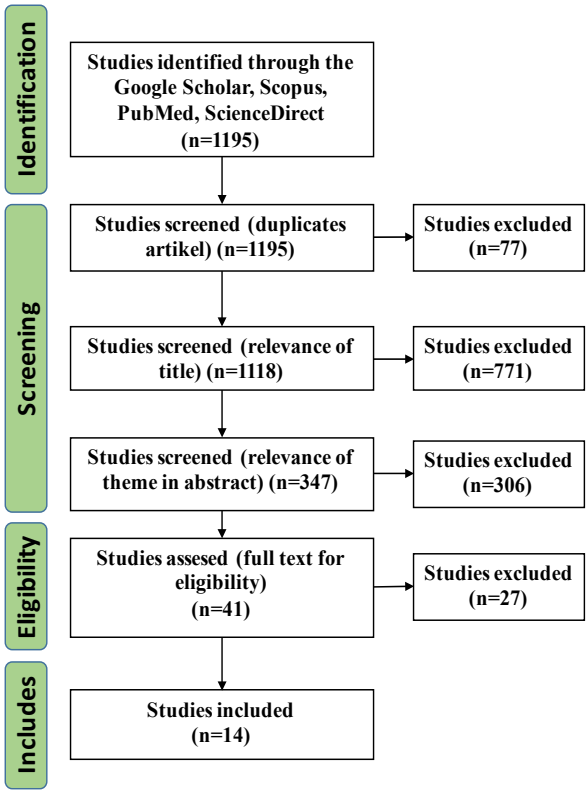

Figure 1. Study selection flow chart

RESULTS

The initial search found 1,195 articles (Google Scholar: 983, Scopus: 162, Pubmed: 8, and ScienceDirect: 42). After checking duplication, identification, screening, and eligibility, 14 articles were found to be deemed eligible and able to answer questions and research objectives, namely to see the description and relationship of risk factors to CWP consisting of dust, duration of exposure, susceptibility and smoking. Furthermore, the author checked the suitability of the 14 articles using the STROBE criteria and continued by carrying out a meta-synthesis. The results of the article review are explained in Table 1.

Table 1. Literature findings

Author/Year/Title	Journal	Results
Rey *et al,* (2015). Underground Coal Mining: Relationship between Coal Dust Levels and Pneumoconiosis, in Two Regions of Colombia, 2014	BioMed Research International, Vol.8: 1-8	The results showed a 35.9% prevalence of pneumoconiosis in the study group (42.3% in Boyacá and 29.9% in Cundinamarca). An association was found between a radiological diagnosis of pneumoconiosis and a moderate risk level of exposure to carbon dust (OR: 2.901, 95% CI: 0.937, 8.982), medium-sized companies (OR: 2.301, 95% CI: 1.260–4.201), more years of mining work than 25 years (OR: 3.222, 95% CI: 1.806–5.748), and a history of smoking for more than one year (OR: 1.479, 95% CI: 0.938–2.334).
Beyan *et al*, (2020). Coal workers' pneumoconiosis and surveillance: A 5-year experience	Eurasian Journal of Pulmonology Vol. 22 No.2 118-122	of a total of 127 coal mine workers, all men with an average age of 40.5 ± 8.9 years, 63 (49.6%) were diagnosed with CWP. The duration of exposure to coal dust ranged from 7 to 390 months, and the average duration of exposure was 129.1 ± 82.2 Months. Of 127 coal mine workers, 49.6% were diagnosed as CWP. There was no significant difference between cases with and without pneumoconiosis in terms of age, smoking (P> 0.05). The duration of dust exposure was significantly higher in miners with pneumoconiosis than in patients without pneumoconiosis (P < 0.05).
Han L *et al,* (2015). Prevalence Characteristics of Coal Workers' Pneumoconiosis (CWP) in a State-Owned Mine in Eastern China	International Journal of Occupational Environmental Research and Public Health Vol. 12 No. 7 7856-7867	The research results showed that 71.11% of the 495 CWP cases were stage I and 90.71% were involved in tunnel or coal mining. The average dust exposure period in CWP patients was 26.7 years, the average latent period was 29.3 years and the average age at diagnosis was 50.3 years. The proportion of CWP diagnosed after ending dust exposure greatly increased over time.
Zhang *et al,* (2018). Study and Application on Risk Assessment Method of Coal Worker Pneumoconiosis Based on Logistic Regression Model	Journal of Risk Analysis and Crisis Response, Vol. 8, No. 3, Hal. 157-162	The results show coal workers are exposed to respirable coal dust at current concentrations for 5 or 10 years, 5 and 10-6, and in 20 or 30 years, it will be between 10-3 and 10-2. If they were exposed to coal dust at this concentration for 30 years, the risk would exceed acceptable risk levels and action would have to be taken. This means that there is a relationship between dust concentration and duration of exposure to pneumoconiosis.
Halldin et al, (2015) Debilitating Lung Disease Among Surface Coal Miners With Underground Mining Tenure	Journal Occupational Environment Medicine Vol. 57 No.1 62-67	Chest radiographs developed progressive massive fibrosis over only a short period of time (11 years). A miner's lung biopsy revealed fibrosis and abundant accumulation of interstitial macrophages containing silica, aluminum silicate, and titanium dust particles. Overexposure to respirable silica results in progressive massive fibrosis among surface coal miners.
Romero *et al,* (2019) Prevalence of pneumoconiosis and spirometric findings in underground mining workers in Cundinamarca, Colombia	Revita de la Faculted de Medicina Vol. 67 No. 4 581-586.	The prevalence of pneumoconiosis was 42.33%. FEV1/FVC ratio (81.75 vs 83.74, p = 0.045) and FF25-75% (84.96 vs 91.95, p < 0.001) mean values were significantly lower in workers with pneumoconiosis. Long-term exposure to coal dust in underground mining workers was shown to be significant for pneumoconiosis while smoking and pneumoconiosis were not found to be significant.
Han R *et al.,* (2015) Polymorphisms in interleukin 17A gene and coal workers' pneumoconiosis risk in a Chinese population.	BMC Pulmonary Medicine Vol.15 No.1 Hal:1–8.	The rs3748067 polymorphism significantly reduced the risk of CWP among cases with dust exposure of more than 27 years (adjusted OR = 0.42, 95% CI = 0.18 - 0.97). Luciferase assay in two cell lines showed that the rs8193036 C>T substitution could reduce IL-17A expression, which was consistent with the findings of this study

Table 1. Literature findings (continued)

Author/Year/Title	Journal	Results
Altınsoy B *et al.,* (2016). Emphysema and airflow obstruction in non-smoking coal miners with pneumoconiosis.	Medical Science Monitor. Vol. 22 Hal:4887–4893	A remarkable association was found between two SNPs (rs3748067 and rs8193036) of the IL-17A gene and disease resistance, and the association was more pronounced in smokers. Unconditional logistic regression analysis showed that the genotypes rs3748067 AA (adjusted OR = 0.43, 95% CI = 0.23 - 0.83) and rs8193036 TT (adjusted OR = 0.59, 95% CI = 0.40 - 0 .86) was associated with a reduced risk of CWP, especially among the smoker subgroup (adjusted OR = 0.34, 95% CI = 0.13 - 0.86 for rs3748076.
Cohen *et al.*, (2016). Lung Pathology in U.S. Coal Workers with Rapidly Progressive Pneumoconiosis Implicates Silica and Silicates	American Journal of Respiratory and Critical Care Medicine, Vol. 193 No. 6 Hal. 673 – 680.	The results of the study showed that in the thirteen cases reviewed, the rapid progression of pneumoconiosis in these coal miners was associated with exposure to high concentrations of silica-containing coal mine dust and respirable silicates.
Kurth *et al.*, (2020). Prevalence of spirometry- defined airflow obstruction in never- smoking working US coal miners by pneumoconiosis status	Occupational and environmental medicine, Vol. 77 No. 4, Hal. 265-267	A higher prevalence of airflow obstruction among never-smoking coal miners with pneumoconiosis compared with those without pneumoconiosis. The prevalence of airflow disorders among nonsmoking coal miners was 7.7% overall, 16.4% among miners with CWP and 32.3% among miners with PMF. Airflow obstruction was significantly associated with CWP and PMF. The prevalence of airflow obstruction was highest in never-smoking miners with PMF (32.3%).
Ulfahimayati *et al*, (2021). Incidence of Pneumoconiosis in Coal Mining Workers at PT. A Sawahlunto City and the Factors That Influence it	Jurnal Respiratory Indonesia Vol.41 No.1 Hal. 51 - 63	The results of the study found that 12 workers (13.3%) experienced pneumoconiosis. Statistical test results showed that age > 50 years (P=0.035), exposure time (P=0.040), mask use (P=0.029), restrictive lung function (P=0.004) and mixed lung function (P=0.006) were associated with incidence of pneumoconiosis. The dominant factor is the use of masks (P=0.049) with OR=5.026. Other related factors are age, length of exposure and lung function abnormalities.
Yong *et al.*, (2018). The Risk of Developing Coal Workers' Pneumoconiosis in a German Inception Cohort of Coal Miners of Ruhr Area - Results after 30 Years of Follow-up	Ann Lung Cancer, Vol. 2, No. 1, Hal. 39-47.	The cumulative incidence rate was 2.34 per 1000 person-years for CWP 0/1 (71 cases) or 1/0 (1 case), no CWP ≥ 1/1 was found. cumulative exposure to respirable quartz demonstrated an increased risk (HR = 1.08; 95% CI: 1.04-1.13). The duration of exposure was a significant factor in the development of CWP while the long-term average concentration of inhaled quartz did not reach the level of significance.
Rodríguez *et al,* (2015). Relation of exposure to coal dust, crystalline silica and pneumoconiosis in workers of underground coalmines.	Indian Journal of Applied Research, Vol. 4 No.3 Hal. 6 – 10	The risk of moderate levels of coal exposure was related to the prevalence of pneumoconiosis and additional factors such as moderate company size, experience equal to or greater than 30 years, and tobacco use for more than one year in underground mine workers in Cundinamarca. No significant relationship was found for crystalline silica.
Ji X *et al.* (2015). Associations of MMP1, MMP2 and MMP3 genes polymorphism with coal workers pneumoconiosis in Chinese han population.	Int. J Environ Res Public Health. 2015;12(11):13901–12.	Individuals with the MMP3 rs522616 GG genotype had a reduced risk of CWP (adjusted OR = 0.72, 95% CI = 0.52–0.99) compared with those with a clear AA/AG genotype. Furthermore, serum MMP3 protein levels measured by enzyme-linked immunoassay assay in the control group were significantly lower than that in the CWP group (p = 0.02). These findings suggest that MMP3 rs522616 polymorphism may contribute to the etiology of CWP in the Chinese population and MMP3 may be a potential diagnostic biomarker for CWP.

DISCUSSION

Effect of dust on CWP

The results of the article review identified the main factor causing CWP to be dust. Continuous accumulation of coal dust in the lungs for a long time causes pneumoconiosis. Lung pathology in coal workers implies the presence of silica dust and silicates indicating exposure in high concentrations(10),(16). The size of coal dust particles is a component that plays a role in causing lung damage(17).

Based on the article review, it is known that coal mine workers inhale dust that exceeds the threshold with high exposure levels (coal dust > 0.70 mg/m³ and silica: > 0.02 mg/m³). The study conducted by Rey, et al. (2015) in Colombia, showed that the prevalence of CWP in the study population was 35.9% with an average dust size exceeding the exposure limit and an average bituminous concentration of 3.27 ± 2.89 mg/m³(9). Research by Yong, et al. (2018) showed the long-term average concentration of coal dust exposure was 2.48 mg/m³ at the end of exposure. Cumulative exposure to inhaled coal dust is 37.1 mg/m³ per year(18). A study by Rodriguez, et al. (2015) found an adjusted dust concentration from TLV-TWA of 3,054 mg/m³ (standard 0.70 mg/m³) obtained in underground miners (19). All articles studied concluded that there was a significant relationship between dust concentration and the incidence of CWP.

Exposure to inhaled coal mine dust creates the development of coal worker pneumoconiosis (CWP) with the main risk factor being exposure to coal dust. Increasing these exposure factors increases the risk of developing CWP(20). The level of dust exposure is determined by the average dust content in the air and the time of exposure to the dust. The lung pathology of coal mine workers shows that pneumoconiosis progresses rapidly when exposed to dust containing silica and silicates in high concentrations (dust > 0.70 mg/m³ and silica > 0.02 mg/m³ for 8 working hours and six days a week)(10). These high exposure levels increase the risk of developing pneumoconiosis(9). Dust levels that are above the threshold value (NAB), namely above 0.15 mg/m³ for 8 hours can cause various diseases including pneumoconiosis.

Effect of exposure/work duration on CWP

The results of a review of seven studies found a relationship between exposure time and pneumoconiosis. Accumulated dust exposure over a long period can cause and worsen pneumoconiosis(18). Beyan, et al. found the average length of exposure in workers with pneumoconiosis was 148.9 months and showed a significant relationship ($p < 0.01$)(20). Rey, et al.'s study. found that the average length of time working in mining was 19.49 years (median 16 years) and proved that there was a significant relationship between length of work and pneumoconiosis ($p < 0.001$)(9). Study Romero, et al. (2019) obtained an average length of work of 21.7 years. Compared to working for < 25 years, working 25 – 29 years has a 2.9 times higher risk, and working ≥ 30 years has a 3.2 times higher risk of developing pneumoconiosis(21). Han L., et al.'s study. (2015) showed that the average dust exposure period of CWP patients was 26.7 years, the average latent period was 29.3 years and the average age at diagnosis was 50.3 years. The proportion of CWP after ending dust exposure increased over time(22). Workers exposed to coal dust who have worked for ≥ 30 years are at high risk of developing pneumoconiosis(19).

Length of exposure is related to length of work which is linearly proportional to a significant increase in lung dysfunction in coal mining workers. The longer a person works and is exposed to coal dust, the more coal dust particles will settle in their respiratory tract. As a result of the literature review, the majority of studies on exposure duration influence the incidence of CWP. The longer the working period means the longer the exposure, the higher the risk of CWP occurring. This happens because workers experience more intense exposure to dust.

Effect of susceptibility on CWP

Individual susceptibility characteristics also contribute to CWP. Genetic factors such as polymorphisms may contribute to the development of CWP. From two articles regarding the relationship between individual susceptibility to CWP, it was identified that there was an influence of individual factors that were susceptible to pneumoconiosis. Ji X., et al.'s study. (2015) showed that MMP3 rs522616 polymorphism may contribute to the cause of CWP in China and is a potential diagnostic biomarker of CWP(23), while the study of Han R., et al. (2015) showed that the rs3748067 AA and rs8193036 TT polymorphism genotypes were associated with a reduced risk of CWP. The rs3748067 polymorphism can significantly reduce the risk of CWP in cases of dust exposure over 27 years (Adjusted OR= 0.42, 95%CI= 0.18–0.97)(24).

Individual susceptibility factors play a role in the development of disease among workers(12). *CWP* is a chronic occupational lung disease characterized by the pathological accumulation of extracellular matrix (ECM) proteins(9),(25), and genetic factors such as polymorphisms contribute to CWP. Matrix metalloproteinases (MMPs) are considered important in ECM maintenance and tissue repair processes. Changes in the activity of MMPs play a role in the altered collagen metabolism of pulmonary fibrosis. MMP1 rs1799750 polymorphism has been reported to alter levels of MMP1 expression and may be associated with a more rapid rate of decline in lung function(24).

Effect of smoking on CWP

The combined effect of smoking and dust is an important factor causing a decline in coal workers' lung function(26). As a result of reviewing five study articles, only one study stated that smoking for more than one year had a significant impact on the CWP of coal mine workers(19), while five other articles concluded that there was no relationship between smoking and the incidence of CWP.

Study Rodriguez, et al. (2015) proved that smoking for more than one year was associated with CWP (OR= 4.437; IC 95%= 2.06 - 9.55; p = 0.001)(19). Beyan, et al.'s study. (2015) showed there was no significant difference between cases with and without CWP in terms of smoking (p>0.05)(20), However, smoking is one of the factors that can disrupt the lung function of mining workers(5). A study by Kurth, et al. (2020) stated that coal miners who do not smoke experience 7.7% airflow obstruction, and severe cases of CWP can present with an obstructive pattern regardless of smoking status(27). Altinsoy, et al.'s study. (2016) concluded that exposure to coal dust is associated with emphysema and/or airflow obstruction even without a history of smoking, however, the difference in the severity of emphysema between non-smoking miners and non-smoking non-miners is around 6 times(28).

Smoking habits are also related to lung function. The combination of exposure to coal dust and smoking worsens a person's lung condition. Long-term smokers are reported to be more susceptible than non-smokers to silicosis and lung disease. The hydrocyanic acid in tobacco smoke can damage the bronchial epithelium and cilia, reducing dust removal ability(29). The results of the article review identified that in general smoking is not the main determining factor for CWP, but rather is a confounding variable because the presence of this factor can influence exposure, but at the same time also influence outcome. In general, the studies analyzed stated that there were no significant differences between cases with or without CWP in terms of smoking. Smoking does not cause an increase in CWP rates, but it can have additional harmful effects on the lungs(30).

CONCLUSIONS

A review of studies from fourteen research articles concluded that dust, exposure time and individual susceptibility have been proven to be risk factors that can influence the occurrence of CWP, while smoking is not a risk factor for CWP whose presence does not increase the incidence of CWP, but can interfere with lung function.

Considering that CWP is a disease that cannot be treated but can be prevented, it is recommended to use personal protective equipment (PPE) when working, especially standard respiratory protective equipment (respirator masks), maintain body stamina with adequate nutritional intake and adequate rest, carry out examinations. health regularly, and do not smoke.

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