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ORIGINAL ARTICLE

Evaluation of small airway dysfunction in patients with pneumoconiosis, a cross-sectional study

Asuman Aslan Kara[1]
ORCID: 0009-0005-4711-4149

Adem Koyuncu[1]
ORCID: 0000-0003-4834-1317

Gülden Sarı[1]
ORCID: 0000-0003-1098-4405

Ceprail Şimşek[1]
ORCID: 0000-0003-4767-6393

ABSTRACT

Objective: Pneumoconiosis is an irreversible, progressive parenchymal lung disease caused by inhalation of mineral dust. Inhaled particles in the working environment can cause inflammation and fibrosis in the lung, affecting all respiratory tracts, including the large and small airways. Our study aimed to evaluate the frequency and risk factors of small airway dysfunction (SAD) in patients diagnosed with pneumoconiosis.

Methods: The study population consisted of 331 patients diagnosed with pneumoconiosis between 01/01/2018 and 31/05/2023. Pneumoconiosis was diagnosed with a history of occupational inorganic dust exposure, radiologic findings compatible with pneumoconiosis, and exclusion of other diagnoses. Two readers evaluated the chest radiographs of the patients according to the International Classification of Pneumoconiosis Radiographs of the International Labor Organization. SAD was defined as at least two FEF50, FEF75, and FEF25-75 measurements below 65% of their predicted values.

Results: SAD was found in 47.7% of the patients. There was a statistically significant difference between age and the prevalence of SAD, but there was no statistically significant difference between smoking status and the prevalence of SAD. It was observed that 41.9% of the patients with pneumoconiosis who had never smoked had SAD. As the cigarette pack-years increased, the incidence of SAD increased. SAD was presented 38.7% in Stage 1, 50.7% in Stage 2, and 57.6% in Stage 3 pneumoconiosis cases. SAD was seen in 35.1% of pneumoconiosis cases without PMF. In pneumoconiosis patients with PMF, the frequency of SAD increased with increasing opacity size.

Conclusion: It was found that the frequency of SAD increased as the stage of pneumoconiosis increased. In patients with pneumoconiosis, SAD was observed in both smokers and never smokers, independent of large airway obstruction. Therefore, early small airway dysfunction should be considered when monitoring the health of patients with pneumoconiosis.

Keywords: Pneumoconiosis, small airway dysfunction, progressive massive fibrosis.

[1]Ankara Atatürk Sanatorium Training and Research Hospital, Department of Occupational Diseases, Ankara, Türkiye.

Corresponding Author: Asuman Aslan Kara
E-mail: drasuaslan@gmail.com

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INTRODUCTION

Pneumoconiosis is an irreversible lung disease caused by prolonged inhalation of inorganic dust and fibers. Since these inhalants are usually encountered in the workplace, they are known as occupational diseases. Inhalation-induced lung diseases are among the most important occupational diseases. The most common occupational mineral dust are silica, asbestos fibers, coal dust, and silicate dust. The development of the disease depends on the susceptibility of the lungs, the size, density, solubility, fibrogenic properties, and duration of exposure of the inhaled particles. These particles can cause inflammation and fibrosis in the lung, affecting all airways, including the large and small airways [1-4].

Inhalation of dust, gases, and vapors at work remains prevalent worldwide and significantly contributes to the burden of occupational respiratory disease [5]. Between 1990 and 2017, pneumoconioses increased by 66% worldwide [6]. The prevalence of pneumoconiosis is approximately 527,500 cases, with more than 60,000 new cases reported worldwide in 2017 [7]. According to 2019 data, it remains a significant public health problem, with 200,000 new cases and 920,000 disability-adjusted life years (DALYs) worldwide [8]. In our country, the true extent of the problem is not fully known, but it is commonly observed that pneumoconiosis constitutes most cases diagnosed with occupational diseases. In this respect, pneumoconiosis is an important public health problem in our country as in the world.

Small airways are less than 2 mm in diameter between the 8th and 23rd bronchial branches. They act as a bridge between the central airways and the gas-exchanging lung compartment and are recognized as the main site of airflow limitation in obstructive lung disease [9,10]. According to recent studies, small airway dysfunction (SAD) is defined as at least two of maximum mid-expiratory flow (MEF), forced expiratory flow 50 (FEF 50%), and forced expiratory flow 75 (FEF 75%) being less than 65% of the expected normal value [11]. SAD is a common but poorly understood respiratory problem. To date, there have been many epidemiologic studies on the contribution of workplace exposure to chronic airflow limitation. Most studies have focused on occupational asthma and occupational chronic obstructive pulmonary disease (COPD) caused by workplace exposure [12]. However, small airway evaluations have not been performed sufficiently. However, a recent study in China evaluated SAD risk factors in pneumoconiosis and emphasized their importance in the follow-up of patients with pneumoconiosis [13]. In our country, there are no studies assessing the development of SAD in patients diagnosed with pneumoconiosis, and it was thought that the evaluation of small airway parameters in the follow-up of patients with pneumoconiosis would contribute to determining the severity of the disease. Therefore, we aimed to evaluate the frequency and risk factors of SAD in patients with pneumoconiosis.

METHODS

Study design

This retrospective study was conducted in the Occupational Diseases Training Clinic of Ankara Atatürk Sanatorium Training and Research Hospital, an important reference center for pneumoconiosis in Turkey. The study was initiated after obtaining the approval of the ethics committee (2012-KAEK-15/2750). Patients over the age of 18 who were diagnosed with pneumoconiosis and had a medical examination report issued between 01/01/2018 and 31/05/2023 were included in the study. Pneumoconiosis was diagnosed with a history of occupational inorganic dust exposure, radiologic findings compatible with pneumoconiosis, and exclusion of other diagnoses. Demographic characteristics, pneumoconiosis stages, detailed occupational history, smoking history, exposure history, pulmonary function tests (PFTs), and radiologic images of the patients at the time of diagnosis were obtained from the hospital information management system and patient files. Patients' current and past employment patterns were recorded in the detailed occupational history, and the types of dust to which they were exposed at their workplace were described. Recorded smoking history was calculated as tobacco pack years by multiplying the average number of cigarettes smoked per day by the total number of years of smoking.

Patients whose spirometry data could not be accessed from their files and the system and whose spirometry results were incompatible were not included in the study. Of the 400 patients diagnosed with pneumoconiosis, 69 patients were excluded because their PFTs were incompatible or could not be accessed, and a total of 331 patients were included in the study (Figure 1). Spirometry was performed using a Zan 100 flow-sensitive spirometry device (ZAN MessgerateGmbH,

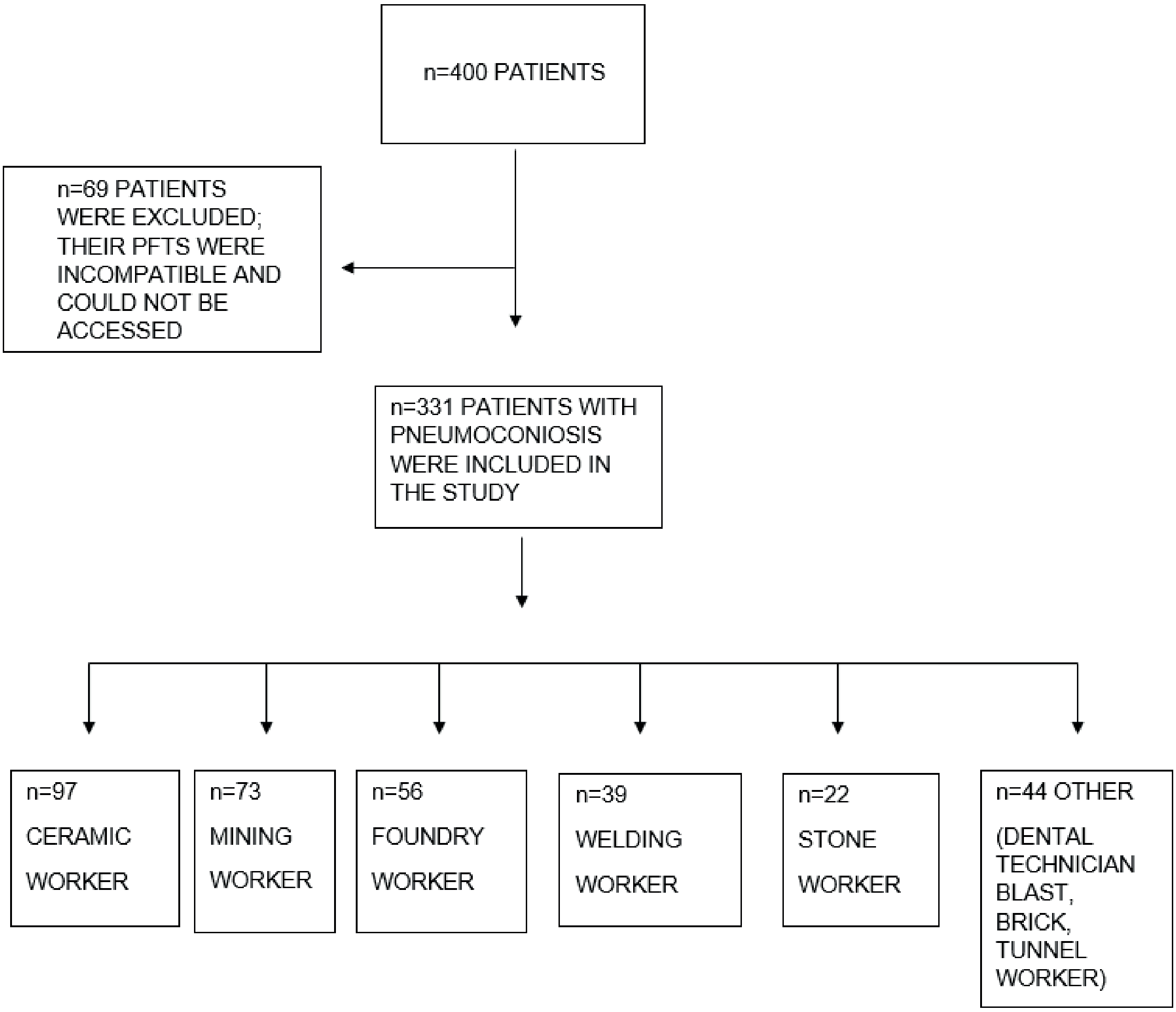

Figure 1. Study group

Oberthulba, Germany). Spirometry was calibrated daily, and temperature and humidity measurements were used for calibration. Spirometry results were analyzed according to the acceptability and reproducibility criteria presented in the ATS/ European Respiratory Society statement updating the standardization of spirometry [14]. Spirometry measurements of the patients were evaluated according to the percentage of reference values.

Chest X-rays were taken with a digital X-ray system. Two readers evaluated chest radiographs according to the International Classification of Pneumoconiosis Radiographs of the International Labor Organization (ILO). Small opacities were defined by profusion, shape (round or irregular), and size. Small opacity profusion was divided into four stages (0, 1, 2, 3), each with three subcategories (0/- to 3/+).

In this study, three expiratory volume parameters, including FEV1, FVC, and FEV1/FVC, and the forced expiratory flow parameter at the 25th, 50th, and 75th percentile of FVC were recorded (FEF50, FEF75, and FEF25-75). In this study, SAD was defined as at least two of maximum mid-expiratory flow (MEF), forced expiratory flow 50 (FEF50 %), and forced expiratory flow 75 (FEF75 %) being less than 65% of the expected normal value.

Statistical analyses

The data of this study were evaluated using the IBM SPSS Statistics 22.0 statistical package program.

Categorical data were presented as number (n) and percentage (%), and numerical data were presented as mean and standard deviation. Data were tested for normality using the Kolmogorov-Smirnov test. In independent groups, t-test was utilized to compare continuous variables between the two groups. The chi-square test was used to compare categorical data. P-value < 0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

The mean age of 331 patients included in the study was 51±11 (30-92), all patients were male, and 269 (81.3%) were smokers. Ninety-seven patients were ceramic workers, 73 were mine workers, 56 were foundry workers, 39 were welding workers, 22 were stone workers, and 44 were working in other occupational groups (dental technician, sandblaster, brick, and tunnel worker). The characteristics of patients with pneumoconiosis are presented in Table 1.

Table 1. Characteristics of the pneumoconiosis patients

		n (%)
Age	51±11 (30-92)	331(100)
Age Group	30-39	38 (%11.5)
	40-49	120 (%36.5)
	50-59	99 (%29.9)
	60-69	45 (%13.6)
	70+	29 (%8.8)
Smoking Status	Smoker	269 (81.3)
	Non-smoker	62 (18.7)
Cigarette (Package/Year)	0-19	187 (%56.5)
	≥20	144 (%43.5)
Occupation	Mine worker	73 (%22.1)
	Foundry worker	56 (%16.9)
	Welding worker	39 (%11.8)
	Stone worker	22 (%6.6)
	Ceramic worker	97 (%29.3)
	Other	44 (%13.3)
Exposure Duration (Year)	0-10	51 (%15.4)
	11-20	164 (49.5)
	21-30	96 (%29)
	≥31	20 (%6.04)
ILO Stage	Stage 1	119 (%36)
	Stage 2	146 (%44.1)
	Stage 3	66 (%19.9)
Large Opacity (PMF)	None	228 (%68.9)
	A	45 (%13.6)
	B	32 (%9.7)
	C	26 (%7.9)
Small Airway Dysfunction	Yes	158 (%47.7)
	None	173 (%52.3)
FVC ≥%80, FEV1/FVC≥%70	Yes	183 (%55.3)
	None	148 (%44.7)

Prevalence of SAD in pneumoconiosis patients

SAD was present in 158 (47.7%) of the patients. A statistically significant difference was found between age distribution and SAD frequency (p<0.001). SAD was found in 41.9% of never smokers with pneumoconiosis. There was no statistically significant difference between smoking status and the incidence of SAD (p=0.327). However, the incidence of SAD increased with increasing cigarette pack years (p=0.002).

SAD pneumoconiosis patients were 38.7% in Stage 1, 50.7% in Stage 2, and 57.6% in Stage 3 (p=0.030). SAD was seen in 35.1% of pneumoconiosis without progressive massive fibrosis (PMF). Pneumoconiosis patients with PMF increased the frequency of SAD with the opacity size (p<0.001).

Of the 331 pneumoconiosis patients, 163 had FEV1<80%, and 77.9% had SAD. In 168 patients, FEV1 was ≥80%, and 18.5% had SAD (p<0.001). One hundred sixteen pneumoconiosis patients had FVC <80% and 71.3% had SAD. 31.3% of those with FVC ≥80% had SAD (p<0.001).

In addition, SAD was found in 26.8% of pneumoconioses with FVC ≥80% and FEV1/FVC≥70%, while SAD was found in 73.6% of those with FVC <80% and FEV1/FVC <70% (p<0.001). SAD was seen in 41.8% of patients with pneumoconiosis with FEV1 ≥80%, FEV1/FVC≥70% (p<0.001). SAD was observed in all 34 patients with pneumoconiosis with FEV1 <80% and FEV1/FVC <70% (Table 2).

Table 2. Association between characteristics of patients with pneumoconiosis and SAD

	Small Airway Dysfunction		p
	NONE	YES	
Age Group			
30-39	21 (%55.3)	17 (%44.7)	**<0.001**
40-49	82 (%68.3)	38 (%31.7)	
50-59	54 (%54.5)	45(%45.5)	
60-69	13 (%28.9)	32 (%71.1)	
70+	3 (%10.3)	26 (%89.7)	
Smoking Status			
Non-smoker	36 (%58.1)	26 (%41.9)	0.327
Smoker	137 (%50.9)	132 (%49.1)	
Package/Year			
0-19	111(%59.4)	76 (%40.6)	**0.002**
≥20	62 (%43.1)	82 (%56.9)	
Occupation			
Mine worker	18 (%24.7)	55 (%75.3)	**<0.001**
Foundry worker	39 (%69.6)	17 (%30.4)	
Welding worker	23 (%59)	16 (%41)	
Stone worker	13 (%59.1)	9 (%40.9)	
Ceramic worker	66 (%68)	31 (%32)	
Other	14 (%31.8)	30 (%68.2)	
ILO Stage			
Stage 1	73 (%61.3)	46 (%38.7)	**0.030**
Stage 2	72 (%49.3)	74 (%50.7)	
Stage 3	28 (42.4)	38 (%57.6)	
Large Opacity (PMF)			
None	148 (%64.9)	80 (%35.1)	**<0.001**
A	13 (%28.9)	32 (%71.1)	
B	8 (25)	24 (%75)	
C	4 (%15.4)	22 (%84.6)	
FVC ≥%80, FEV1/FVC≥%70			
None	39 (%26.4)	109 (%73.6)	**<0.001**
Yes	134 (%73.2)	49 (%26.8)	
FEV1≥%80, FEV1/FVC≥%70			
None	0	34 (%100)	**<0.001**
Yes	173 (%58.2)	124 (%41.8)	
FEV1			
<%80	36 (%22.1)	127 (%77.9)	**<0.001**
≥%80	137 (%81.5)	31 (%18.5)	
FVC			
<%80	39 (%28.7)	97 (%71.3)	**<0.001**
≥%80	134 (%6.7)	61 (%31.3)	
FEV1/FVC <%70			
None	173(%58.6)	122 (%41.4)	**<0.001**
Yes	0	36(%100)	

DISCUSSION

This retrospective cross-sectional study evaluated the association between pneumoconiosis and small airway dysfunction. In our study, age, heavy smoking, pneumoconiosis stage, occupational group, duration of exposure, and presence of PMF were independent risk factors for developing SAD in patients with pneumoconiosis. In the study, SAD was mostly seen in mine workers, which may be related to more intense dust exposure of mine workers underground.

Until now, few studies have demonstrated the development of SAD in patients with pneumoconiosis. In the early 1970s, Seaton et al. evaluated dynamic compliance in 25 miners with evidence of pneumoconiosis and normal spirometry and found that dynamic compliance was decreased in 15 of them. Small airways were pointed out as the site of abnormality in this decrease in dynamic compliance [15]. In a study designed in California, autopsies of 112 agricultural workers showed wall thickening, remodeling, and inflammation associated with carbonaceous and mineral dust accumulation in small airways, with little or no accumulation in large airways [12].

In a study by Churg et al., mineral dust-related small airway pathology was found in lung tissue from 174 patients who underwent lung resection for lung carcinoma. It was reported that 53 of these patients were exposed to mineral dust, and 13 of these 53 patients had mineral dust-related airway disease pathology in the respiratory bronchioles. When patients with small airway disease associated with mineral dust in histopathology were compared with the control group, FEV1, FVC, and FEF 25-75 values were found to be significantly decreased [16].

In recent studies showing the development of SAD in patients with pneumoconiosis, the prevalence of SAD was reported as 43.5% and 66.3% [11]. In our study, in which we used the same diagnostic criteria for SAD, the prevalence was 47.7%. In addition, studies have emphasized that SAD may be one of the early functional abnormalities of lung damage developing in pneumoconiosis, and it has been reported that the prevalence of SAD increases as the stage of pneumoconiosis increases [13]. Our study found that the frequency of SAD increased significantly with increasing disease stages in patients with pneumoconiosis. In addition, for the first time in our research, it was found that the incidence of SAD increased as the size of the large opacity increased in patients with PMF.

The results of studies evaluating the effect of smoking on airway pathologies associated with occupational exposure are conflicting. One study reported that smoking did not affect small airway function in occupationally induced airway pathologies and was consistent with a previous study investigating biological dust. In another study, respiratory symptoms were more frequent in smokers, but smoking did not change the relationship between occupation and pulmonary function [17]. In our study, no relationship was found between smoking status and SAD due to different occupational exposure, in line with the literature data. Still, the relationship between the development of SAD in smokers who smoked 20 pack-years or more was statistically significant.

Jong et al. investigated the association of occupational exposure to vapors, gases, dust, and smoke with small airway obstruction. They showed that the effects of occupational exposure in the small airways were a primary response in those with normal FEV1/FVC and normal estimated FEV1 values. They emphasized that this was independent of the effects on the large airways. It has also been shown that smoking does not affect small airway function in those whose small airways are affected by occupational exposure [18]. In our study, consistent with this study, SAD was observed independently of large airways in 26.8% of pneumoconiosis patients with normal FVC, FEV1/FVC, and 41.8% of pneumoconiosis patients with normal FEV1, FEV1/FVC.

Although our study evaluated SAD development and risk factors in a large series of pneumoconiosis cases, it has some limitations. The limitations include the small number of patients, heterogeneous occupational groups, and retrospective study; therefore, the relationship between the symptoms and SAD could not be evaluated.

CONCLUSION

In our study, a significant correlation was found between the stage of pneumoconiosis and SAD. In post-occupational pneumoconiosis, SAD was observed independently of large airway obstruction in both smokers and never smokers. Therefore, early small airway obstruction should be considered when monitoring the health of patients with pneumoconiosis.

Author contribution

Study conception and design: AAK, AK, GS, and CŞ; data collection: AAK, AK, and GS; analysis and interpretation of results: AAK and AK; draft manuscript preparation: AAK, AK, and GS. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the Ankara Atatürk Sanatorium Education and Research Hospital Ethics Committee (Protocol no: 2012-KAEK-15/2750).

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Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

[1] Farzaneh MR, Jamshidiha F, Kowsarian S. Inhalational lung disease. Int J Occup Environ Med. 2010 Jan;1(1):11-20.

[2] Perret JL, Plush B, Lachapelle P, et al. Coal mine dust lung disease in the modern era. Respirology. 2017 May;22(4):662-670.

[3] Karkhanis VS, Joshi JM. Pneumoconioses. Indian J Chest Dis Allied Sci. 2013 Jan-Mar;55(1):25-34.

[4] Hoy RF, Brims F. Occupational lung diseases in Australia. Med J Aust. 2017 Nov 20;207(10):443-448.

[5] Driscoll T, Nelson DI, Steenland K, et al. The global burden of non-malignant respiratory disease due to occupational airborne exposures. Am J Ind Med. 2005 Dec;48(6):432-45.

[6] Shi P, Xing X, Xi S, et al. Trends in global, regional and national incidence of pneumoconiosis caused by different aetiologies: an analysis from the Global Burden of Disease Study 2017. Occup Environ Med. 2020 Jun;77(6):407-414.

[7] GBD 2017 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018 Nov 10;392(10159):1789-1858.

[8] GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020 Oct 17;396(10258):1204-1222.

[9] Lipworth B, Manoharan A, Anderson W. Unlocking the quiet zone: the small airway asthma phenotype. Lancet Respir Med. 2014 Jun;2(6):497-506.

[10] Burgel PR. The role of small airways in obstructive airway diseases. Eur Respir Rev. 2011 Mar;20(119):23-33. doi: 10.1183/09059180.00010410. Erratum in: Eur Respir Rev. 2011 Jun;20(120):123. Dosage error in article text. Erratum in: Eur Respir Rev. 2011 Jun;20(120):124. PMID: 21357889; PMCID: PMC9487720.

[11] Xiao D, Chen Z, Wu S, [et al. China Pulmonary Health Study Group. Prevalence and risk factors of small airway dysfunction, and association with smoking, in China: findings from a national cross-sectional study. Lancet Respir Med. 2020 Nov;8(11):1081-1093.

[12] Balmes J, Becklake M, Blanc P, et al. Environmental and Occupational Health Assembly, American Thoracic Society. American Thoracic Society Statement: Occupational contribution to the burden of airway disease. Am J Respir Crit Care Med. 2003 Mar 1;167(5):787-97.

[13] Fan Y, Ma R, Du X, et al. Small airway dysfunction in pneumoconiosis: a cross-sectional study. BMC Pulm Med. 2022 Apr 28;22(1):167.

[14] Miller MR, Hankinson J, Brusasco V, et al. ATS/ERS Task Force. Standardisation of spirometry. Eur Respir J. 2005 Aug;26(2):319-38.

[15] Seaton A, Lapp NL, Morgan WK. Lung mechanics and frequency dependence of compliance in coal miners. J Clin Invest 1972;51(5):1203–1211.

[16] Churg A, Wright JL, Wiggs B, et al. Small airways disease and mineral dust exposure. Prevalence, structure, and function. Am Rev Respir Dis. 1985 Jan;131(1):139-43.

[17] Sunyer J, Kogevinas M, Kromhout H, et al. Pulmonary ventilatory defects and occupational exposures in a population-based study in Spain. Spanish Group of the European Community Respiratory Health Survey. Am J Respir Crit Care Med. 1998 Feb;157(2):512-7.

[18] De Jong K, Boezen HM, Kromhout H, et al. LifeLines Cohort Study. Occupational exposure to vapors, gases, dusts, and fumes is associated with small airways obstruction. Am J Respir Crit Care Med. 2014 Feb 15;189(4):487-90.