Pulmonary Function test of Mine workers exposed to Respirable Dust in Jharia Coalfield India

Deepa Agarwal, Jai Krishna Pandey, Asim Kumar Pal

Abstract

Respiratory chronic airway disorders and early damage of pulmonary system predict by Spirometry. Occupational exposures to coal dust affect the different systems of the body. The present study has focused on the coal workers who are continuously exposed to air pollutants such as coal dust. Study group of 170 male workers working in coal mines for more than ten years, consists of 66 non-alcoholic and non-smokers, 52 tobacco chewers, 29 smokers and 23 alcoholic. The pulmonary function test was assessed using computerized spirometer. Spirometry test revealed 27.64% of workers having Mild, 29.41% moderate, and 5.88% severe obstruction pattern on PFT. For both the age groups of workers (25-40 and 41-55) having smoking and alcoholic habits, FEV1/FVC values were found more significantly declining (65-71% and 46-53%).Cumulative exposures to respirable dust are the most important risk factors for exposed coal workers. The results suggest that there in a need to improve control measures and the health status of workers engaged in coal mine dust.

Keywords: Spirometry, Pulmonary function test, Coal mine, Vital Capacity, Forced vital capacity, Forced expiratory volume, Respirable coal dust

Introduction

Coal mining is an ancient occupation, long recognized as being arduous and liable to injury and disease. Coal mine dust is a mixture that contains more than 50 substances. The mineral content depends on the particle size of the dust and the coal seam. The most commonly found minerals in coal mine dust include kaolinite, illite, calcite, pyrite and quartz (silica).In developing countries, owing to the growing world economy, the increase in coal production and utilization results in numerous miners exposed to the health hazards of coal mine dust[1, 2]. Dust from high rank coals usually contains more silica particles than dust of lower rank coals. Most workplace exposure to coal dust occurs during mining; however exposure can also occur during handling of the mined product during cleaning and blending processes or bulk handling at large coal fired facilities [3]. The effect of occupational silica exposure on pulmonary function resulted in a consistent association between increased pulmonary function abnormalities and estimated measures of cumulative silica exposure within the current allowable OSHA regulatory level [4].

*Agarwal D, Respiratory Protection Laboratory, CSIR - Central Institute of Mining & Fuel Research, Dhanbad, India.

Pandey J K, Sr. Principal Scientist and Head, Respiratory Protection Laboratory, CSIR - Central Institute of Mining & Fuel Research, Dhanbad, India.

Pal A K, Professor, Department of Environmental Science and Engineering, Indian School of Mines, Dhanbad India.

Occupational exposure to crystalline silica can occur in any workplace situation where air borne dust, containing a proportion of crystalline silica, is generated. Industries where crystalline silica is present include quarrying, mining, mineral processing (eg drying, grinding, bagging and handling), slate working, stone crushing and dressing, foundry work, brick and tile making, some refractory processes, construction work, including work with stone, concrete, brick and some insulation boards, tunnelling, building restoration and in the pottery and ceramic industries. A number of studies have demonstrated that there is a loss of lung function for quarry and stone workers as a result of exposure to respirable crystalline silica (RCS) [4-6]. Particles of size 5 micron or smaller (PM5) form stable suspension in the air. During inhalation, bigger size particles, e.g.> 10 microns, are filtered out at the nose itself by very fine hairs in the nose. About 50% of the particles of 5 micron size generally reach the respiratory track and its branches and most of them are accumulated there itself, with only 1-2% reaching the alveoli of the lungs. As the size of the dust particles decreases further, the dust's intercepting capability of the respiratory track also decreases and more dust reaches to alveoli. Thus respiratory system gets affected (i.e., clogged due to these depositions), depending of the particles size of the dust inhaled, causing commonly prevalent respiratory diseases among the coal workers, e.g. Asthma and Pneumoconiosis.

Silicosis is a form of pneumoconiosis caused by inhalation of crystalline silica dust, and is marked by inflammation and scarring in forms of nodular lesions in the upper lobes of the lungs [7]. The most common form of silicosis (chronic) will often develop between 15 to 45 years after first exposure, but certain rare forms of the disease can occur after a single heavy dose or heavy exposures to a very high concentration of silica in a short period of time. Workers with Silicosis may have following symptoms: Shortness of breath following physical exertion, severe and chronic cough, fatigue, loss of appetite, chest pains and fevers. The primary feature that develops in lungs of silica quartz exposed workers is nodule formation in the upper zones of the lung [8]. Nodule formation is usually the result of many years of exposure to relatively low levels of dust that contain silica quartz [9]. The classical silicotic nodule is usually located in the area of the respiratory bronchiole. The nodule is composed of reticulin fibres in the periphery and collagen fibres in the center. Fibroblastic activity is usually evident around the periphery of the concentric lesion [10]. The airway and blood vessels are frequently destroyed by being entrapped in the fibrotic nodule. The diagnosis of silicosis generally rests upon history of substantial exposure to silica dusts and compatible radiological features, together with the exclusion of other competing diagnoses, like miliary tuberculosis, fungal infections, sarcoidosis, idiopathic pulmonary fibrosis, other interstitial lung diseases, or carcinomotosis. Lung tissue changes in progressive silicosis are often detected by chest x-ray before they cause any symptoms. Pulmonary function tests will be used to evaluate lung function and confirm the presence of lung disorders. These may include spirometry and lung volume measurement to detect any restriction of normal lung expansion or obstruction of air flow, peak flow measurement to detect narrowing of the airways, and diffusing capacity to assess the efficiency of gas absorption into the blood. Spirometry measures the volume of air (liters) exhaled or inhaled by a person as a function of time. The amount of air displaced by a maximal exhalation or inhalation maneuver is called the vital capacity (VC). If aspiratory flows are reduced out of proportion to expiratory flows, variable extra thoracic (upper airway) obstruction may be inferred [11,12].

In this paper spirometry studies was made for the assessment of prevalence of Pneumoconiosis in miners who were working in a difficult environment of coal mines with a specific aim to focus on health and respiratory problem due to coal dust.

Material and Method

The present study was conducted in the Jamadoba colliery of BCCL, Jharia. The group consisted of 170 coal workers males in which ninety three workers were in age group of 25-40 years and seventy seven workers were in age group of 41-55 years. On personal enquiry, out of the 170 workers, 52 persons were found habituated with chewing tobacco, 29 people were smokers, 23 persons were alcoholic and remaining workers did not have any addiction. Subjects with clinical abnormalities of the neuromuscular diseases, known cases of gross anemia, diabetes mellitus, pulmonary tuberculosis, bronchial asthma, chronic bronchiectasis, and malignancy were excluded from the study. The subjects who had undergone abdominal or chest surgery were also excluded from the study. Fig 1 displays the graphical representation of addiction according to age group.

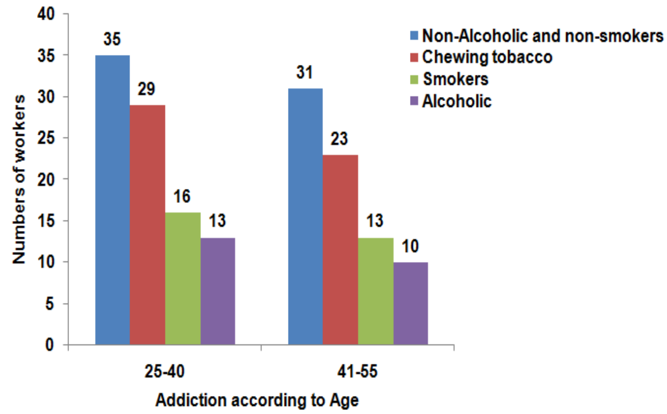

Figure: 1 Graphical Representation of Addiction According to Age Group

Figure Legends: The group consisted of 170 coal workers males in which ninety three workers were in age group of 25-40 years and seventy seven workers were in age group of 41-55 years. In age group of 25-40 mine workers 35 were Non alcoholic and non-smoker,29 were tobacco chewer, 16 were smoker,13 were alcoholic and in age group of 41-55 mine workers 31 were Non-alcoholic and non smoker, 23 were tobacco chewer,13 were smoker,10 were alcoholic.

Pulmonary Function Tests

The spirometry test was performed with the help of spirometry (Vitalograph ALPHA Touch, SKU: 65602) as shown in Fig 2. In the spirometry, an air flow transducer is placed next to the mouthpiece, which converts air flow into electrical signals, the latter being integrated to give the volume and flow at a particular time. The advantages of employing such a spirometry are that it is quite handy-and hence portable as well as useful in field work. Besides, its operation is also very simple. Spirometric indices help in the diagnosis of both obstructive and restrictive type of ventilatory defects. All the pulmonary function tests were done on the subjects comfortably in an upright position. During the test, the subject was adequately encouraged to perform their optimum level and also a nose clip was applied during the entire maneuver. Tests were repeated three times and the best matching results were considered for analysis. The parameters measured by the apparatus were the Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second, the ratio of FEV_1/FVC, etc. with graphic curves. The FVC is defined as the volume of the air a person exhales with forceful expiration after minimal inspiration. Normally, it is reached within 3-4 seconds.

Airways restriction however prolongs this time. The normal FVC volume for males is 4.8 L, whereas for females it is 3.1 L. The forced expiratory volume (FEV) is the volume of air exhaled in a given time (usually 1second , referred to as FEV_1).Yet, another important parameter derived from spirometric data is the FEV_1/FVC ratio, which is a useful index for assessing the magnitude of airway obstruction. The spirometry test results performed on different categories of workers.

Fig: 2 Spirometry (Vitalograph ALPHA Touch,SKU:65602)

The parameters measured and recorded included:

- FEV_1 (Forced Expired Volume in 1 Second) measured in Litres, which is the volume of air exhaled in the 1st second.
- FVC (Forced Vital Capacity) measured in Litres, which is the total amount of air exhaled.
- FEV_1/FVC is the ratio of the two measures (%) and provides an indication of airflow obstruction.

Result

The data of pulmonary function tests were presented for each parameter VC, FVC, FEV1& FEV1/FVC% in different category of workers were shown in Table 1.

Before attempting to interpret the result of subject workers, it is borne in mind that spirometry test are merely an indicator and do not necessarily lead to exact diagnosis; nevertheless they do define the functional pulmonary abnormalities accurately, which are useful to assess the respiratory ailments.

Table: 1 showing the differences of the various parameters of pulmonary function tests among different category of workers.

Age group of workers (in years)	Designation	Spirometry Parameters				Remarks
		VC(L)	FVC(L)	FEV_1 (L)	FEV_1/FVC (%)	
25-40 (Non-alcohol and non-smokers)	Belt Operator (n = 5)	2.97±0.01	2.84±0.01	2.26±0.02	79.66±1.53	Normal
	Mining Sirdar (n = 6)	2.65±0.01	2.54±0.01	2.03±0.00	80.08±0.52	Normal
	Overman (n = 8)	3.02±0.00	2.80±0.00	2.24±0.00	79.86±0.37	Normal
	Mechanical Fitter (n = 8)	3.82±0.01	3.66±0.01	2.94±0.00	80.33±0.21	Normal
	Helper (n = 8)	2.26±0.01	3.04±0.01	2.68±0.02	88.41±0.84	Normal
25-40 (Chewing tobacco)	Belt Operator (n = 7)	2.27±0.01	2.47±0.01	1.95±0.01	75.25±0.82	Normal
	Mining Sirdar (n = 6)	2.21±0.00	2.11±0.00	1.67±0.01	79.23±1.21	Normal
	Overman (n = 6)	1.76±0.01	1.77±0.01	1.24±0.01	70.01±0.59	Normal
	Mechanical Fitter (n = 4)	2.90±0.01	2.81±0.00	2.21±0.00	78.82±0.30	Normal
	Helper (n = 6)	2.68±0.00	1.97±0.00	1.73±0.03	87.62±2.19	Normal
25-40 (Smokers)	Belt Operator (n = 4)	2.45±0.00	2.55±0.00	1.81±0.00	71.10±0.48	Mild Obstruction
	Mining Sirdar (n = 4)	1.74±0.00	1.28±0.01	0.87±0.01	67.97±1.52	Mild Obstruction
	Overman (n = 3)	2.54±0.00	1.57±0.00	1.02±0.00	65.11±0.52	Mild Obstruction
	Mechanical Fitter	2.64±0.00	1.85±0.00	1.22±0.00	65.88±0.51	Mild

ISSN 2229-5518

	(n = 3)					Obstruction
	Helper (n = 2)	2.54±0.00	1.78±0.01	1.16±0.01	64.42±0.53	Mild Obstruction
25-40 (Alcoholic)	Belt Operator (n = 2)	1.91±0.00	1.68±0.01	0.915±0.01	54.30±0.19	Moderate Obstruction
	Mining Sirdar (n = 3)	2.13±0.00	2.31±0.01	1.36±0.01	58.78±0.31	Moderate Obstruction
	Overman (n = 2)	1.91±0.01	1.57±0.01	0.92±0.01	58.41±1.16	Moderate Obstruction
	Mechanical Fitter (n = 3)	2.21±0.00	1.53±0.01	0.88±0.01	57.70±0.51	Moderate Obstruction
	Helper (n =3)	2.21±0.00	1.66±0.01	0.95±0.01	57.40±0.47	Moderate Obstruction
41-55 (Non-alcohol and non-smokers)	Belt Operator (n = 8)	2.31±0.02	1.70±0.01	1.08±0.01	63.29±0.85	Mild Obstruction
	Mining Sirdar (n = 5)	2.56±0.01	1.81±0.01	1.176±0.01	64.76±0.69	Mild Obstruction
	Overman (n = 7)	2.47±0.01	1.77±0.01	1.18±0.01	66.77±0.93	Mild Obstruction
	Mechanical Fitter (n = 6)	1.72±0.01	1.23±0.01	0.85±0.01	69.30±0.96	Mild Obstruction
	Helper (n = 5)	2.33±0.01	3.64±0.01	2.222±0.01	61.04±0.45	Mild Obstruction
41-55 (Chewing tobacco)	Belt Operator (n = 5)	2.32±0.01	3.96±0.01	2.14±0.01	54.06±0.46	Moderate Obstruction
	Mining Sirdar (n = 5)	3.17±0.01	2.762±0.01	1.61±0.01	58.29±0.45	Moderate Obstruction
	Overman (n = 4)	3.067±0.01	2.63±0.01	1.48±0.01	56.11±0.50	Moderate Obstruction
	Mechanical Fitter (n = 4)	2.14±0.01	2.32±0.01	1.34±0.01	58.02±0.90	Moderate Obstruction
	Helper (n = 5)	3.07±0.01	2.67±0.01	1.45±0.01	54.26±0.70	Moderate Obstruction
41-55 (Smokers)	Belt Operator (n = 2)	2.05±0.07	1.20±0.01	0.56±0.035	46.89±3.20	Moderate Obstruction
	Mining Sirdar (n = 3)	2.05±0.02	1.12±0.02	0.55±0.015	49.43±2.15	Moderate Obstruction
	Overman (n = 2)	1.96±0.02	1.07±0.02	0.53±0.014	49.56±2.63	Moderate Obstruction
	Mechanical Fitter (n = 4)	2.19±0.06	1.46±0.01	0.73±0.018	50.34±1.45	Moderate Obstruction
	Helper (n = 2)	1.94±0.014	1.05±0.02	0.56±0.028	53.11±3.74	Moderate Obstruction
41-55 (Alcohol)	Belt Operator (n = 3)	1.92±0.02	1.12±0.02	0.44±0.025	39.63±1.85	Severe Obstruction
	Mining Sirdar (n = 2)	2.1±0.28	1.05±0.02	0.39±0.021	37.60±1.01	Severe Obstruction
	Overman (n =2)	2.02±0.02	1.03±0.02	0.43±0.021	42.27±3.20	Severe Obstruction
	Mechanical Fitter (n = 2)	1.92±0.02	0.94±0.02	0.35±0.021	37.55±1.40	Severe Obstruction

	Helper (n = 1)	1.95	1.12	0.47	41.96	Severe Obstruction

Legends: Values are presented in geometric means: Mean ±Standard Deviation. VC: Vital Capacity, FVC: Forced vital capacity, FEV_1: Forced expiratory volume in one second between two age groups of mine workers

For diagnosis purposes, the commonly used indices are FVC, FEV_1&FEV_1/FVC ratio.FEV_1/FVC is a useful index for assessing the magnitude of airway obstruction. This is so, because timed volumes are dependent on vital capacity and body size and hence there are variations. As is obvious, expressing the timed volume as the ratio of vital capacity reduces this variability.FEV_1 in obstructive in FVC in restrictive diseases are the best parameters for monitoring the progression of these diseases. Spirometric parameters are calculated from the curves. Usually, it is best to record the maximal readings of forced expiratory volume for one second (FEV_1), and forced vital capacity (FVC). The best test curve is regarded as the one which gives the largest sum of FEV_1 and FVC. Among the all pulmonary parameters observed in Table 1 for different categories of workers, a critical examination of these results leads to the following observations:

a) The predicted FEV_1 % is generally used to grade severity in patients with obstructive, restrictive and mixed pulmonary defects. Pellegrino *et al.*, (2005)[13] provided data which can be used to rate the level of severity as shown in Table 2 [14].

Table 2: Severity of any spirometry abnormality based on the forced expiratory volume in one second (FEV_1). (From Pellegrino et al, 2005, p.957).

Degree of severity	FEV_1 % of predicted
Mild	> 70
Moderate	60 – 69
Moderately severe	50 – 59
Severe	35 – 49
Very severe	s < 35

b) The value of Vital Capacity (VC) for the subjects of all age groups ranged between 1.725±0.017 to 3.82±0.013which is closer to normal values.

c) The values of Forced Vital Capacity (FVC) of different categories of workers were seen in the range between 0.945±0.021 to 3.966±0.018, which is much below the normal value of 4.8L for males. It signifies that even after putting the maximal efforts by the workers, the amount of air exhaled by them is not adequate. The reduction in FVC values signifies that there is both restriction and obstruction types of lungs problem.

d) Among the all pulmonary parameters observed, the FVC and FEV_1/FVC have been observed significantly declining for the smokers and alcoholic workers. The reason for this could be that coal dust in combination with SPM, NO_x, SO_2 and tobacco smoke, obstruct the air flow in the lungs to greater extend.

e) The FEV_1/FVC values in workers of age group 25-40 years (non-alcohol and non-smokers) are normal (i.e., 80%) as compared to workers of age group 41-55 years (non-alcohol and non-smokers) having Mild Obstruction (FEV_1/FVC values is near to 69%).

f) In workers of age group 25-40 years having habit of chewing tobacco, the FEV_1/FVC values were near normal (around 80%) but in age group of 41-55 years of same worker category, these values were significantly declined (54-58%) and having Moderate Obstruction.

g) Workers of age group 25-40 years and 41-55 years having smoking habit, the FEV_1/FVC values were found more significantly declining (65-71% and 46-53%) and were seen to develop Mild Obstruction & Moderate Obstruction.

h) The value of FEV_1/FVC for workers of age group 41-55 having habit of alcohol consumption were found in the category of Severe Obstruction as compared to workers of age group 25-40 years (having Moderate Obstruction).

i) These results signify that workers of coal mines especially 41-55 year age group are more susceptible to be affected by respiratory diseases. Therefore, adequate preventive measures are required to be taken to ensure their safety and prevention from health hazards.

j) Townsend *et al.*, (2011) also concludes the presence of airways obstruction when FEV_1/FVC and FEV_1 are both less than the lower limit of normal (LLN)[15].

Discussion

Inhalation of coal dust is an important cause of pneumoconiosis in India [16].Some workers also suffer due to silicosis. Damage to the lungs from silicosis is irreversible; there is no standard treatment other than reducing symptoms and treating complications. Lung tissue changes due to silicosis are often detected by a chest x-ray before they cause any symptoms. If dust exposure is stopped at this point, further progression of the disease can sometimes be prevented. Cigarette smoking is the major risk factor for COPD. However, relevant information from the literature published within the last years, either on general population samples or on workplaces, indicates that about 15% of all cases of COPD are work-related [17]. A study of white South African gold miners showed that the forced expiratory volume in one second (FEV_1), and the FEV_1/FVC ratio, adjusted for age, height, and tobacco smoking, decreased with increasing cumulative respirable dust exposure, in both smokers and non-smokers. The average cumulative dust exposed attributed loss in lung function in miners [18]. The present study demonstrates that prolonged exposure to coal dust markedly decreased the pulmonary function that were exposed to coal dust more than 15 years working experience showed a significant reduction in FVC, FEV_1/FVC in compare to non-exposed workers. In tobacco chewers and smokers the respiratory problem is due to the nicotine present in it. Nicotine is readily absorbed from the respiratory tract, buccal membrane, skin and causes the combined effect or activation of parasympathetic ganglia and cholinergic nerve endings result in increased tone and motor activity of the bowel along with nausea, vomiting and occasional diarrhea [19, 20].That is why smoking, tobacco chewing and alcohol addicted persons have more chance to develop respiratory problem including toxic environment of mines. This reduction is not due to increasing age of subjects. It is likely that this decline in lung function is due to the factors such as exposure to air pollutants like carbon mineral compositon may also contain trace elemets, Arsencic, lead, mangenese, titanium, beryllium uranium [21] lung function tests are decline plino carta etal studied in young coal miners FVC,FEV_1 [22] . Cumulative exposure increasing prevalence less than 80% predicted. Miners respiratory disease are also due to the exposure to the coal dust and sulphuric acid which is produced by rock wastes or spoil discarded in piles and when exposed to water and oxygen and also the exposure of sulphur bed present in mines [23] .The present work also shows that age group 40-55 have developed severe obstruction in the lungs. The reason for this is obviously due to the fact that in the underground mining operational environment, the dispersion of pollutants associated with coal dust is restricted in a limited area, as compare to open cast environment, where the pollutants in comparatively much lesser concentration, get dissipated in the open air.

Conclusion

A large number of epidemiological studies have shown that long term exposure to the particles is associated with adverse effects on health. While various preventive measures from technological perspective are widely adopted, measures depending on the clinical aspects may go a long way to control the disease. The research findings are summarized below:

- The impairment of lung function was significantly associated with increasing age, duration of dust exposure, tobacco chewing, smoking and alcohol status.
- Thus, it can be concluded from this study that even low dust level exposure for longer duration can result in lung and lung function involvement. Hence, coal workers, because of their occupational exposure to silica dust, are at increased risk of lung and lung function involvement.
- Our results support the need to lower allowable air levels of silica and increase efforts to encourage cessation of cigarette smoking among silica-exposed workers.
- Avoiding long exposure to dust in workplace environment and exercising control breathing, and not deep breathing
- Decline in lung function is not entirely due to increasing age of subjects. The factors such as exposure to air pollutants like coal dust having (trace elements, e.g., arsenic, lead, manganese, titanium, beryllium, uranium, etc also contribute in a significant manner.
- Development of biometric database of vulnerable class of workers will help diagnosis of the disease.
- Besides periodical health checkup at regular interval, a scheme of increased heath monitoring exercise as a function of service period and age of workers may be more helpful in early diagnosis of disease.
- The recent study reveals significant stressful environment for as they are more prone to various life threatening respiratory diseases including silicosis.

Acknowledgement

The authors are grateful to Director, CSIR- Central Institute of Mining and Fuel Research (CIMFR), Dhanbad for permission to publish the Paper. They extend their gratefulness to the management of Tata Iron and Steel Company (TISCO), Jamadoba, Dhanbad for their help in conducting the study.

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