REVIEW ARTICLE

A Review of Effect of Occupational Exposure of Silica on Lung Functions

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Abstract

Millions and millions of people are working daily in an atmosphere filled with respirable dust particles. Crystalline silica is an important dust particle which is generated in many occupations like stone carving, quarrying, sand blasting, shipping, ceramic industry, etc. The workers who are constantly exposed to the silica particle on a regular basis are more likely to develop occupational lung diseases like pneumoconiosis, chronic obstructive pulmonary disease (COPD), bronchitis, etc. These cause a decline in the lung functions. The purpose of this review article is to narrate the effects of occupational exposure of silica on lung functions. The spirometry results revealed a decline in forced expiratory volume 1 second, forced vital capacity, and ratio of forced expiratory volume 1 second to forced vital capacity. This reveals the need for proper education of the employees to take adequate preventive measures during working like wearing protective personal equipment, periodic screening, etc.

Keywords: Chronic obstructive pulmonary disease, Silica, Silicosis, Spirometry pulmonary function tests.

SBV Journal of Basic, Clinical and Applied Health Science (2022): 10.5005/jp-journals-10082-03150

Introduction

Millions and millions of people are working daily in an atmosphere filled with respirable dust particles. These workers inhale dust particles like gases, fumes, silica particles, organic dusts, and inorganic dusts which are risk factors in developing pneumoconiosis.[1] Crystalline silica particles are considered as one of the most common and important minerals which is used in various industries like mining, stone carving, sand blasting, ceramic, and shipping industries.[2,3] Occupational lung diseases like pneumoconiosis are caused by exposure of crystalline silica particles in the workplace.[4] Lung function impairment is the most common respiratory problem among workers exposed to dusts.[5,6] The purpose of this review article is to narrate the effects of occupational exposure of silica on lung functions.

Effect of Occupational Exposure of Silica on Lung Functions

The effect of occupational exposure of silica on lung functions discussed under the following heads:

- Lung function tests
- Lung function impairment in workplace
- Silicosis

Lung Function Tests

Lung function tests are indicated when diseases such as asthma, COPD, and pulmonary fibrosis are suspected. There are many pulmonary function tests that are performed. Spirometry is the most common and nonexpensive test that can be performed easily.

Pulmonary function tests that are routinely performed are as follows:

- Spirometry
- Plethysmography
- DLCO
- ABG
- Pulse oximetry
- Peak flow meter
- Helium dilution method
- Nitrogen washout method
- 6MWT
- FeNO
- Cardiopulmonary exercise test (CPET)
- Bronchial challenge test
- Reversibility test

Some of the important pulmonary function tests are discussed below:

Spirometry: A spirometer is a device, which consists of a mouthpiece, and it is attached to a small electronic machine. A clip will be placed in the nose, and the patient will be asked to take a deep breath and then asked to exhale as fast and as long as possible.[7]

The disadvantage of this test is that residual volume, functional residual capacity, and total lung capacity cannot be measured by this test.

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How to cite this article: Priya SV, Vallabaneni V, Ragulan R, Varghese J. A Review of Effect of Occupational Exposure of Silica on Lung Functions. J Basic Clin Appl Health Sci 2022;5(2):43–46.

Source of support: Nil

Conflict of interest: None

Plethysmography: Patient is made to sit inside an air-tight box that appears like a phone booth.[8] Plethysmography can provide more precise results and further information like the residual volume, functional residual capacity, and total lung capacity.

In the above-mentioned tests, the following lung volumes and capacities will be measured, and the results will be marked in a graph, based on which the pattern of lung dysfunction can be assessed.

- Forced vital capacity (FVC)
- Forced expiratory volume in one second (FEV1)
- The ratio of the two volumes (FEV1/FVC).

The graphs obtained in the results contain comparison between volume and time and flow and volume. The curve below displays the normal and various types of lung function abnormalities like obstructive pattern, restrictive pattern, and mixed pattern.[9]

The components of lung volume that can be assessed can be with the help of PFTs are as follows:

- Tidal volume (Vt)
- Inspiratory reserve volume (IRV)
- Expiratory reserve volume (ERV)
- Residual volume (RV)
- Vital capacity (VC)
- Functional residual capacity (FRC)
- Inspiratory capacity (IC), and
- Total lung capacity (TLC).[10]

The following are the steps (assessing validity and reproducibility, determining the abnormality, bronchodilator response, assessing severity, and evaluation of flow volume loops) involved in the assessing the PFTs:[11]

- Assess validity
- Assess reproducibility
- Determine abnormality—obstruction versus restriction
- Look for bronchodilator response
- Define severity
- Assess change over time
- Evaluate flow volume loops.

Lung Function Impairment in Workplace

Globally, it is projected that there are 2.3 million deaths each year due to diseases that are attributed to the workplace.[12] Occupational dust exposure is the leading contributor to a greater prevalence of lung function impairment.[13,14] Many immunologic and nonimmunologic mechanisms are accountable for the development of occupational lung disease.[15]

Silicosis is acquired when a person is continuously exposed to coal dust. Over a period of time, this can give rise to inflammation of lung tissue resulting in scarring and fibrosis. This can result in irretrievable lung damage and dyspnea.

Silicosis

Silicosis is highly prevalent. Around 5 million people are exposed to respirable particles of silica dust worldwide.[16] The prevalence of silicosis is high among the occupation where respirable silica dust is involved, as much as 55% of workers in India involved in works like coal mining and quarrying of sedimentary rock have been noticed to have silicosis.[17]

The following list of jobs is more susceptible to the silicosis:

- Mining: surface or underground mining (tunneling)
- Milling: ground silica for abrasives and filler
- Quarrying
- Sandblasting: e.g., buildings, preparing steel for painting
- Pottery: ceramic or clay work
- Grinding: polishing using silica wheels
- Stonework
- Foundry work: grinding, molding, and chipping
- Refractory brick work
- Glass making: to polish and as an abrasive
- Boiler work: cleaning boilers
- Manufacture of abrasives.[18]

The forms of silicosis are acute, chronic, and accelerated.

- **Acute silicosis** develops within a few months up to 2 years after inhaling silica dust in remarkably high concentrations. Clinical features are severe dyspnea, cough, fever, fatigue, and loss of weight. Mostly, patients with this form of silicosis have durable health; on the contrary, some patients may die early.
- **Chronic silicosis** is the frequent form of silicosis. This can develop after inhaling silica dust in low or moderate quantity over a period of about 15–20 years. These patients can be asymptomatic or may present with symptoms like cough and dyspnea. To diagnose asymptomatic patients, it is important to screen the employees with imaging modalities like chest X-ray. As the disease advances, the employees may have features of poor gas exchange like hypoxia or hypercapnia. In the advanced stages, the employees may experience severe dyspnea, chest pain, weakness, or respiratory distress.
- **Accelerated silicosis** develops due to more severe exposure of lesser duration (5–10 years) than the chronic form of silicosis. Clinical features are severe dyspnea, fatigue, and weight loss. Silica particles cause lung injury by direct cytotoxicity, production of reactive oxygen species (ROS) and reactive nitrogen species (RNS), secretion of inflammatory and fibrotic mediators, lung remodeling through collagen and elastin deposition, and cell death by apoptosis.[18]

Results

Thongtip et al. studied the outcomes of high silica exposure on various respiratory diseases among the stone-mortar employees from northern regions of Thailand. In their study, they observed the high PM10 containing crystalline silica exposure among stone-mortar workers (compared to the agricultural workers) and this is associated with decline in lung function among the exposed stone-mortar workers.[19]

Ghotkar et al. studied the involvement of lung and pulmonary function tests among the 80 stone quarry workers from Nagpur. They found that the prevalence of respiratory morbidity among the study subjects was 32.5%. The lung function impairment correlated positively with the increasing age, duration of exposure to dust particles, smoking status, and presence of preexisting airways diseases.[20]

Aghilinejad et al. did a cross-sectional study among stone-cutter workers from Malayer city (Azandarian) between 2008 and 2009. In their study, they reported that about 16 workers (8.9%) had silicosis according to chest imaging and 35 workers had impaired lung functions as evident from their spirometry findings.[21]

Hnizdo et al. studied the loss of lung function associated with exposure to silica dust among South African gold miners. They reported that there was increased loss of pulmonary function among gold miners compared to general population.[22]

Rathod et al. studied the effect of silica exposure on lung functions among stone crushers in Marathwada region. This was a cross-sectional observational study which concluded that there is a decrease in lung functions as the duration of exposure increases.[23]

Asgarabad et al. studied the levels of exposure to particles and respiratory symptoms in stone carvers of Kerman, Iran. They did a cross-sectional study comparing 67 male workers exposed to stone carving dust and 67 unexposed workers who were matched in regard to different characteristics evaluated. They observed increased respiratory symptoms and decline in spirometric parameters among the stone carvers.[24]

Sheikh et al. studied the effect of risk factors like duration of exposure, smoking status, and job profile on pulmonary function among 100 male stone quarry workers in Jammu City, India. They selected the study participants through multistage random sampling technique. They reported that the duration of exposure is a significant determinant of deterioration of lung functions.[25]

Bahrami et al. compared pulmonary function among 322 workers in Iran and concluded that FEV1 and FVC were declined among the workers in stone grinders.[26]

Rajavel et al. studied the prevalence of silicosis, silico-tuberculosis, and other respiratory diseases along with lung functions among 174 workers employed in the sandstone mines located in Jodhpur, Rajasthan. In their study, they observed that abnormal lung function was seen in about 89.2% of employees.[27]

Htun et al. studied the lung function impairment and workplace control measures among marble stone carvers in Sa-Kyin Village, Madayar Township, Myanmar. They did a cross-sectional descriptive study among 120 marble stone carvers. Spirometry testing showed 55.8% had lung function impairment.

Gholamie et al. studied the spirometric parameters among workers in fire brick industry. They concluded that the spirometric parameters like FEV1 and FVC were all reduced in the exposed group of workers when compared to the unexposed group.[28]

Johncy et al. studied the effect of dust exposure on lung functions among workers employed in the construction sites. They concluded that there was a significant decrease in the FVC, FEV_1, PEFR, %FEV1/FVC, and $FEF_{25–75\%}$ among the employees, and they correlated with the duration of exposure to the dust particles.[29]

Conclusion

The spirometry results revealed a decline in forced expiratory volume 1 second, forced vital capacity, and ratio of forced expiratory volume 1 second to forced vital capacity. This reveals the need for proper education of the employees to take adequate preventive measures during working like wearing protective personal equipment, periodic screening, and stop further exposure when there is a decline in lung function.

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