Scholars Journal of Applied Medical Sciences (SJAMS)
Abbreviated Key Title: Sch. J. App. Med. Sci.
©Scholars Academic and Scientific Publisher
A Unit of Scholars Academic and Scientific Society, India
www.saspublisher.com

ISSN 2320-6691 (Online)
ISSN 2347-954X (Print)

Physiology

Silica-Induced Airway Damage: A Matched Comparative Study of Pulmonary Function Test among Stone Crushers of North India

Sheikh Junaid Aziz[1], Zahid Ali Khan[2*], Sunil Sachdev[3], Tazeen Khan[4], Nusrat Chauhan[5]
[1]Demonstrator, Department of Physiology, M.M. Medical College and Hospital, Kumarhatti, Solan, Himachal Pradesh, India
[2]Assistant professor, Department of Community Medicine, M.M. Institute of Medical Sciences and Research, Mullana, Ambala, Haryana, India
[3]Professor & Head, Department of Physiology, Government Medical College, Jammu, India
[4]Demonstrator, Department of Physiology, M.M. Institute of Medical Sciences and Research, Mullana, Ambala, Haryana, India
[5]Post Graduate Scholar, Department of Physiology, Government Medical College, Jammu, India

Original Research Article

***Corresponding author**
Zahid Ali Khan

Article History
Received: 09.03.2018
Accepted: 18.03.2018
Published: 30.03.2018

DOI:
10.21276/sjams.2018.6.3.66

Abstract: Lungs continuously exchange the gases between the environment and the blood and thus are the first to face the onslaught from the environmental pollutants. The silica present in the stones is one of the topmost pollutants that adversely affect the lungs. Irreversible pathological changes in the airways occur on chronic silica dust exposure with presentation varying from mild symptoms to debilitating illness. These changes are reflected in form of impaired lung function tests. This cross-sectional study was designed to determine the effect of silica on pulmonary function test of stone crusher workers of Jammu region. The study was carried out among 18 to 55 years aged 100 male stone crusher workers and 100 age, gender, height and weight matched controls. The information regarding anthropometry, occupational history and medical history was collected with the help of a predesigned structured questionnaire. Pulmonary function tests were performed with the help of computerized spirometer, DTSpiro and tested for statistical difference among exposure and control groups by independent t-test. The Mean ± SD of pulmonary function test parameters including forced vital capacity (FVC), forced expiratory volumes (FEV), flow rates (including PEFR and FEF) except FEF_{75} and Maximum voluntary ventilation (MVV) were significantly reduced among stone crushers compared to control subjects. Among chronic respiratory problems, cough was the most common symptom reported in 26% stone crushers, followed by breathlessness in 20%, phlegm in 18% and chest tightness in 14% stone crushers. Chronic exposure to silica dust is associated with lung function impairment. Lack of availability of treatment for damage to airways demands strict implementation of preventive measures at the crusher sites.
Keywords: Lung function, Silica, Stone crusher workers, Respiratory problems.

INTRODUCTION

Occupational health problems usually arise as a result of direct exposure to environmental factors which may be physical, chemical or biological in nature. Recent estimates by WHO reveal that 12.6 million deaths each year accounting for 23% of all deaths worldwide and 22% of the global disease burden can be attributed to environment. Out of 133 diseases or injuries categorized by WHO, 101 were significantly associated with the environmental factors. These estimates vary across different regions due to differences in environmental exposures and access to health care [1].

Respiratory impairment due to environmental factors is known since ancient times. Lungs are directly exposed to atmospheric air and thus are predisposed to detrimental effects of various air contaminants [2]. Chronic exposure of lung to these contaminants in the working place can result in illness [3]. Variety of particulate matter suspended in the air affects lung function and result in an irreversible condition known as pneumoconiosis. Impaired lung function has been reported in workers of various industries like cotton, coal mining, grain/flour mill, tobacco, barley, talc and in stone processing industries [4].

In India, approximately 11.5 million workers are exposed to silica dust in both organized and unorganized sectors [5]. Stone processing industry due to unique working conditions and environmental factors is associated with a very high degree of respiratory morbidity. The preventive measures against inhalation of dust particle are generally poor especially in the unorganized sector due to lack of concerns regarding occupational health. Non availability of Occupational Health & Safety services especially in developing countries can be attributed to inadequate strategies and policies for occupational workers [6].

The stone contains free silica and the stone crushing process release a high level of respirable crystalline silica dust in the working environment [7]. The greater the reduction in size during subsequent crushing stages from larger to smaller ones, higher is the particulate emission. The inhaled silica particles are removed from the lung at a very slow rate and continue to exert their effect even after cessation of the dust exposure. Chronic exposure to silica dust ultimately ends in an irreversible condition called silicosis that affects airway patency and lung parenchyma. Fibrotic and proliferative changes occur that cannot be reversed with the current treatment facilities available, thus lending urgency to their prevention [3].

Health impact in the form of airway obstruction and other respiratory symptoms due to silica dust exposure in this industry is well documented [8-10]. Changes occurring in the respiratory system caused by prolonged silica dust exposure lead to a reduction in the pulmonary function tests values. Periodic measurement of lung functions would thus help in detection of lung abnormalities in the early stages. Impaired lung function as a result of chronic silica dust exposure among stone crushers has been reported in previous studies done in India [11-14] and abroad [15-17] but no such study has been conducted in this part of the country. Hence, the present study was designed to evaluate the respiratory effects of occupational exposure to silica dust in stone crushers of Jammu region.

MATERIALS AND METHODS

The present study was conducted among 100 stone crusher workers of Stone Crusher units located in the vicinity of Jammu city and its outskirts. 100 healthy subjects not exposed to silica dust matched for age, gender, height and weight comprised the control group. The sample size was estimated on the basis of findings of a study by Shaik A *et al.*, [14] and the maximum sample size was obtained by taking FEV_3 values from the study. Taking Mean ± SD values of FEV_3 in stone crusher (2.5014 ± 1.075) and control group (2.830 ± 0.405) from the study a sample size of 97 subjects in each group was obtained at 95% confidence level and 80% power. Finally, 100 subjects in each of the exposure and control groups were taken in the study

Subjects were selected by multistage random sampling technique. The information about the locations of various crusher units was furnished from the concerned local bodies and 10 crusher units were selected randomly. From each of the 10 crusher units selected, 10 subjects willing to participate in the study were randomly selected. These comprised of male workers aged 18 to 55 years and exposed to dust at least for a minimum of one year. Subjects who had past h/o cardio-respiratory illness e.g. TB, bronchial asthma etc., past h/o neuro-muscular diseases with gross clinical abnormalities in the thoracic cage and vertebral column and subjects who had past h/o thoracic or abdominal surgery were excluded from the study.

After seeking permission from the concerned authority and detailing them about the purpose of the study, the eligible subjects were selected after taking a detailed history and thorough examination. Pulmonary function tests were performed with the help of computerized spirometer, DTSpiro (Maestro Medline System Ltd, Himachal Pradesh). All the participants were informed about the study in detail to avoid the anxiety in the subjects and to develop a good rapport. Three readings were recorded and best of the three was taken for the calculation. The lung function test parameters recorded were forced vital capacity (FVC), forced expiratory volumes ($FEV_{0.5}$, FEV_1, FEV_3, $FEV_{0.5\%}$, $FEV_{1\%}$, and $FEV_{3\%}$), flow rates (including PEFR and FEF_{25}, FEF_{50}, FEF_{25-75}, $FEF_{0.2-1.2}$) and Maximum voluntary ventilation (MVV). Institutional Ethics Committee permission was sought before collecting the data.

The data collected was analyzed by SPSS version 20 statistical software and tested for normality distribution by Shapiro Wilk test that revealed data to be normally distributed. 'Students independent t-test' was applied to determine the significance of difference in the lung function test parameters between the exposure and the control groups.

RESULTS

The baseline physiological characteristics like age, weight, height and body surface area (BSA) that affects pulmonary function tests were comparable among stone crusher and control subjects (Table-1). All the vitals including respiratory rate, pulse rate, systolic blood pressure and diastolic blood pressure were slightly higher in stone crushers compared to controls although the differences were statistically non-significant.

Table-1: Comparison of baseline characteristics in the exposure and the control groups

	Stone Crushers, (n=100) Mean ± SD	Controls, (n=100) Mean ± SD	p value
Age (yrs)	34.94 ± 9.81	32.87 ± 9.14	0.124
Weight (kgs)	61.11 ± 13.01	60.65 ± 8.92	0.771
Height (cms)	166.09 ± 7.83	167.98 ± 6.90	0.072
B.S.A (sqm)	1.67 ± 0.18	1.68 ± 0.14	0.612

Table-2: Comparison of pulmonary function tests in the exposure and the control groups

	Stone Crushers (n=100) Mean ± SD	Controls (n=100) Mean ± SD	p value
FVC (Liters)	3.17 ± 0.74	3.77 ± 0.82	<0.001
FEV.5 (Liters)	1.15 ± 0.69	2.36 ± 0.48	<0.001
FEV1 (Liters)	2.45 ± 0.8	3.14 ± 0.67	<0.001
FEV3 (Liters)	3.07 ± 0.76	3.73 ± 0.78	<0.001
FEV.5/FVC (%)	35.71 ± 19.02	63.29 ± 12.76	<0.001
FEV1/FVC (%)	75.86 ± 15.74	82.92 ± 9.94	<0.001
FEV3/FVC (%)	95.42 ± 4.21	97.67 ± 2.98	<0.001
FEF_{25} (Liters/sec)	4.79 ± 1.81	7.08 ± 1.42	<0.001
FEF_{50} (Liters/sec)	3.84 ± 1.6	4.59 ± 1.83	0.002
FEF_{75} (Liters/sec)	2.14 ± 0.96	2.33 ± 1.4	0.263
FEF_{25-75} (Liters/sec)	3.41 ± 1.39	4.02 ± 1.62	0.004
$FEF_{0.2-1.2}$ (Liters/sec)	2.52 ± 0.81	2.93 ± 0.87	0.001
PEFR (Liters/sec)	5.29 ± 1.77	7.61 ± 1.58	<0.001
MVV (Liters/min)	90.69 ± 13.13	105.91 ± 11.38	<0.001

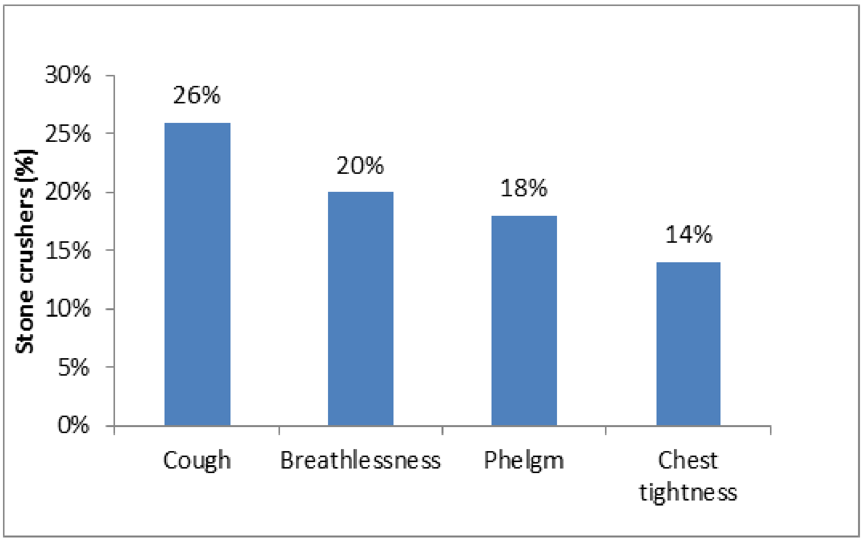

Fig-1: Prevalence of various respiratory symptoms among stone crushers

The Mean ± SD of pulmonary function test parameters including forced vital capacity (FVC), forced expiratory volumes (FEV), flow rates (including PEFR and FEF) except FEF_{75} and Maximum voluntary ventilation (MVV) were significantly reduced among stone crushers compared to control subjects (Table-2).

Stone crushers had not only reduced lung function but also suffered from respiratory morbidity. Among chronic respiratory problems, cough was the most common symptom reported in 26% stone crushers, followed by breathlessness in 20%, phlegm in 18% and chest tightness in 14% stone crushers (Fig-1).

DISCUSSION

Silica associated diseases remain an important public health concern because of its association with multiple diseases and increased mortality. Many operations involved in stone crusher plants including crushing, screening, material handling and transportation are potential sources of dust emission with a high concentration at crusher feed and discharge points. Exposure to silica dust affects airway patency and lung parenchyma and particularly walls of respiratory bronchioles and alveolar ducts [18]. The key event in the genesis of pulmonary disease is the interaction between the silica particle and alveolar macrophages [19]. Secretion of inflammatory cells and fibrogenic growth factors in airway epithelium results in proliferation of fibroblast and collagen synthesis initiating a fibrogenic response [20]. This process leads to irreversible fibrotic changes in the lungs resulting in the reduction of lung function.

We observed a highly significant reduction in forced vital capacity (FVC) and forced expiratory volumes ($FEV_{0.5}$, FEV_1, FEV_3, $FEV_{0.5\%}$, $FEV_{1\%}$ and $FEV_{3\%}$) in stone crusher workers compared to controls. Previous studies have also reported a reduction in mean values of FVC [13, 16, 17], $FEV_{0.5}$ [21], FEV_1 [16, 21] FEV_3 [14], $FEV_{0.5}$/FVC% [21] and FEV_1/FVC [13, 21] among workers exposed to silica dust.

FVC is very sensitive to diseases that affect the lung elasticity and its mechanical properties. FVC, FEV_1 and FEV_1/FVC not only indicate presence and severity of obstructive or restrictive pattern but also give an estimate of overall respiratory impairment [22]. $FEV_{0.5}$ represents the rapidity with which an individual can ventilate his lungs. Forced expiratory volumes and the corresponding ratios later than 1 sec have not been used frequently for lung function testing, although FEV_3/FVC has been asserted to be of value [23]. An isolated reduction in FEV_3/FVC may occur in airway injury resulting from hyperinflation and air trapping [24]. FEV_3/FVC has been found to be superior to the FEV_1/FVC in the detection of abnormal airway obstruction in smokers [25].

Expiratory flow rates including PEFR, FEF_{25}, FEF_{50}, FEF_{25-75}, and $FEF_{0.2-1.2}$ were all significantly reduced in stone crushers than the control group. These findings are consistent with many studies that also reported statistically significant reduction in mean PEFR [14, 26], FEF_{25} [21], FEF_{50} [21, 27], FEF_{75} [21, 27], FEF_{25-75} [12, 21, 27] and $FEF_{0.2-1.2}$ [21] values in silica dust exposed workers. Silica dust exposure leads to a reduction of expiratory flow rates (FEF) mainly due to fibrous tissue formation and inflammatory infiltrates in the airways and lung parenchyma [20]. Besides these inflammatory and structural alterations, airflow obstruction occurs as a result of mucus gland hyperplasia and hypersecretion of mucus in conducting airways [28]. However current evidence suggests that increased secretion of mucus without structural alterations in airways is unlikely to cause significant airflow obstruction [20].

We also observed a significant reduction in MVV among stone crushers compared to controls which is in agreement with findings of previous studies [29, 30]. It is a dynamic test of lung function and is considered to be a good guideline for the mechanical efficiency of lungs as both the neuromuscular and respiratory systems are evaluated. Besides providing measures of lung volume changes and resistance offered by airways, it also gives an assessment of respiratory muscle functioning and thorax-lung complex compliance [31]. A Significant reduction in MVV may indicate insufficient neuromuscular reserve, abnormal respiratory mechanics, or an inadequate effort.

CONCLUSION

Exposure to silica dust is an important occupational health hazard to stone crusher workers. It is considered as an important etiological factor for respiratory morbidity and pulmonary function impairment, depicted by the reduction in lung function test parameters. As chronic silica dust exposure causes irreversible damage to the airways with limitation in the availability of curative treatment, the adoption of preventive measures is important to reduce the morbidity and mortality associated with silica dust exposure.

REFERENCES

1. Prüss-Üstün A, Wolf J, Corvalán C, Bos R, and Neira M. Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. World Health Organization; 2016.
2. Morgan WKC, Seaton A. Silicosis. In: Occupational lung diseases. 3rd ed. Philadelphia: WB Saunders Company; 1995. p.222–37.
3. Andrew MC. Occupational lung diseases. In: Thurlbeck's Pathology of the Lung. 3rd edition. New York: Thieme; 2005. p.769.
4. Garshick E, Schenker MB, Dosman JA. Occupationally induced airway obstruction. Med Clin North Am. 1996;80(4):851–78.
5. Jindal SK. Silicosis in India: past and present. Curr Opin Pulm Med. 2013;19(2):163-8.
6. Mandal AK. Strategies and policies deteriorate occupational health situation in India: A review based on social determinant framework. Indian J Occup Environ Med. 2009;13(3):113-20.
7. Tiwari RR, Sharma YK, Saiyed HN. Peak Expiratory Flow: A Study among Silica-exposed Workers, India. Indian J. Occup. Environ. Med. 2004;8(1):7-10.
8. Gupta SP, Garg AK, Gupta OP. Silicosis amongst stone cutters. J. Assoc. Physicians Ind. 1969;17:163-72.
9. Gupta SP, Bajaj A, Jain AL, Vasudeva YL. Clinical and radiological studies in silicosis: based on a study of the disease amongst stone-cutters. Indian J Med Res. 1972;60(9):1309-15.
10. Deshmukh PA. Chest Diseases in Industry. Ind. J. Tuber. 1967;31:189.
11. Ghotkar VB, Maldhure BR, Zodpey SP. Involvement of Lung and Lung Function Tests in

Stone Quarry Workers. Ind. J. Tub. 1995;42:155-160.
12. Rathod SB, Mane SB, Handergulle SS, Kekan D. Pulmonary function tests in stone crushers. Indian J. Physiol. Pharmacol. 2014;58(3):302-305.
13. Mirdha P, Soni ND, Choudhary K, Solanki S, Sagu R. Pulmonary function test in stone crusher plant workers. Sch. J. App. Med. Sci. 2015;3(5C):1989-1991.
14. Shaik A, Afroze MKH, Latha M, Khan SK, Khatoon S, Reddy PV. Lung function test in quarry workers. International Journal of Innovative Research & Development 2015;4(1):50-55.
15. Hertzberg VS, Rosenman KD, Reilly MJ, Rice CH. Effect of occupational silica exposure on pulmonary function. Chest. 200;122(2):721-8.
16. Draid MM, Ben-Elhaj KM, Ali AM, Schmid KK, Gibbs SG. Lung function impact from working in the pre-revolution Libyan quarry industry. Int J Environ Res Public Health. 2015;12(5):5006-12.
17. Isara AR, Adam VY, Aigbokhaode AQ, Alenoghena IO. Respiratory symptoms and ventilatory functions among quarry workers in Edo state, Nigeria. Pan Afr Med J. 2016;23:212.
18. Andrew C, Joanne LW. Small Airways Disease Caused by Mineral Dusts. Appl Occupation Environ Hyg. 1998;13(8):617–620.
19. Allison AC, Harrington JS, Birbeck M. An examination of the cytotoxic effects of silica on macrophages. J Exp Med. 1966;124:141-154.
20. Hnizdo E, Vallyathan V. Chronic obstructive pulmonary disease due to occupational exposure to silica dust: a review of epidemiological and pathological evidence. Occup Environ Med. 2003;60:237–243.
21. Subhashini AS, Satchidhanandam N. Maximal expiratory flow volume curve in quarry workers. Indian J. Physiol. Pharmacol. 2002;46(1):78-84.
22. Barreiro TJ, Perillo I. An approach to interpreting spirometry. Am Fam Physician 2004;69(5):1107-14.
23. Hankinson JL, Odenkranz JR, Fedan KB. Spirometric reference values from a sample of the general US population. Am J Respir Crit Care Med.1999;159(1):179-187.
24. Morris ZO, Coz A, Starosta D. An isolated reduction of the FEV_3/FVC ratio is an indicator of mild lung injury. Chest 2013;144(4):1117-23.
25. Hansen JE, Porszasz J, Casaburi R, Stringer WW. Re-Defining Lower Limit of Normal for FEV(1)/FEV(6), FEV(1)/FVC, FEV(3)/FEV(6) and FEV(3)/FVC to Improve Detection of Airway Obstruction. Chronic Obstr Pulm Dis. 2015;2(2):94-102.
26. Singh SK, Chowdhary GR, Purohit G. Assessment of impact of high particulate concentration on peak expiratory flow rate of lungs of sand stone quarry workers. Int J Environ Res Pub Health 2006;3(4):355–359.
27. Choudat D, Frisch C, Barrat G, Kholti AE, Conso F. Occupational exposure to amorphous silica dust and pulmonary function. British J Indust Med. 1990;47:763-766.
28. Maestrelli P, Saetta M, Mapp CE, Fabbri LM. Remodeling in response to infection and injury. Airway inflammation and hypersecretion of mucus in smoking subjects with chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 2001;164:S76–80.
29. Vyas S. To Compare The Effects Of Marble And Stone Dust On Lung Volumes And Capacity. Natl J Integr Res Med. 2013;4(3):23-38
30. Singh SK, Patel D, Purohit G. Reduction in Maximum Voluntary Ventilation of lungs of Sand Stone Quarry Workers: A Case study. Journal of Medical Science and Clinical Research 2015;3(3):4954-58
31. Sheldon RL. Pulmonary Function Testing. In Wilkins RL, Krider SJ. Clinical assessment in respiratory care. 4th Edition, Mosby, St. Louis; 2000. p141-160.