

Effects of Prolonged Silica Exposure on Pulmonary Function Among Stone Quarry Workers in South India

Sindhu R¹, Karthiyanee Kutty², Vinutha Shankar MS³

¹Department of Physiology, Manipal TATA Medical College, Manipal Academy of Higher Education, Manipal.

^{2,3}Department of Physiology, Sri Devraj Urs Medical College, SDUAHER, Kolar, India

Corresponding Author: Sindhu R

DOI: <https://doi.org/10.52403/ijhsr.20231044>

ABSTRACT

Background: Occupational lung diseases are prevalent within the quarry worker community due to the substantial dust emissions within quarrying environments. Inhaling this dust is an occupational hazard that poses health risks to on-site workers. To mitigate these risks and facilitate early detection of potential lung damage, pulmonary function tests play a pivotal role. These tests offer an objective and quantifiable assessment of lung function, aiding in the timely identification of any respiratory impairments among quarry workers.

Aims: To assess the pulmonary functions in stone quarry workers and compare them with the unexposed population, to find its correlation with the duration of work in stone quarry workers, and to assess the occupational category that is affected the most.

Materials and methods: A cross-sectional study was done on 200 quarry workers in and around Kolar and 200 unexposed populations. Pulmonary function tests (PFT) were recorded using RMS-PFT machine. The pulmonary function test parameters among the quarry workers were assessed in the various occupational categories.

Results: PFT of quarry workers was significantly reduced as compared to that of the unexposed group ($p < 0.001$). Lung impairment increased with increasing duration of exposure to dust in years among the quarry workers. Lung impairment was found to be the most among the loaders followed by stone grinders, drillers, blasters, and stone cutters. Supervisors were found to be the least affected.

Conclusion: Lung impairment among quarry workers depends on the duration of exposure to dust as well as the dust load. Quarry workers were found to have a Restrictive type of lung disease. Quarry workers must be educated regarding the use of personal protective equipment.

Keywords: PFT (Pulmonary function test), Quarry workers, Restrictive lung disease.

INTRODUCTION

In the bustling quarries of South India, where the earth's riches are hewn from the ground, a resilient workforce toils amid clouds of dust. These workers of the quarry, construction and mining industry, face a formidable occupational hazard - prolonged exposure to silica dust. The quarry workers inhaling the dust are primarily known to suffer from respiratory illnesses. Individuals working in quarry sites are exposed to a

high concentration of dust mainly containing silica which is a main component of sand, rock, and mineral ores. The respirable dust they are exposed to is of different concentrations and particulate sizes depending on the site they work. The higher the exposure and longer the exposure, the greater the chances of the lungs being affected early. The fine crystalline particle of silica enters the lungs through respiration causing lung impairment that causes illness

disturbing the daily activities of the individual which in turn will affect his/her family and become a socioeconomic burden for the rest of their life.¹

Occupational health hazards are prevalent in industrialized countries, but in a developing country like India, millions of people are involved in labor like stone grinding, stone cutting, stone drilling, blasting, stone crushing etc. for their livelihood.² One of the studies shows that stone crushers are dustier compared to stone mining areas. It was also noted that the workers in these areas were exposed to high levels of respirable dust.³ Additionally, there is evidence that silica exposure has synergistic effects with tobacco smoking in causing accelerated lung function decline. The morbidity and mortality due to Silica related diseases are less in developed countries as they adopt effective dust control measures, but the same is not seen in developing countries like India.⁴

This study was designed to assess lung function among stone quarry workers in the Kolar region of South India and compare it to an unexposed control group. The effects of duration of silica exposure and smoking history on lung function were evaluated. Regular spirometry screening of individual workers in quarries provides an objective measure of respiratory status and allows early detection of impairment. This study also aims to find the respiratory health status of the quarry workers in and around Kolar, increase their awareness regarding the disease, and educate them on preventive measures.

MATERIALS & METHODS

Study Design and Setting

This cross-sectional study was conducted among stone quarry workers in the Kolar region of Karnataka, India. Kolar has extensive granite quarries and stone-crushing operations, providing employment for thousands of workers.

Study Population

The target population included male stone quarry workers aged 18-40 years working in

the Kolar region. The comparison group was males aged 18-40 years without quarry work exposure.

Sample Size

The sample size was calculated using estimates of 50% prevalence of abnormal lung function in exposed and unexposed groups, 95% confidence, 80% power, and 10% allowable error. The required sample size was 193 participants per group. Accounting for non-response, the final sample included 200 quarry workers (exposed) and 200 unexposed participants.

Sampling Technique

Purposive sampling was used to recruit participants. Quarry units in the Kolar region were approached and workers were invited to participate. Unexposed participants were recruited from the same communities.

Inclusion and Exclusion Criteria

Inclusion criteria were male quarry workers aged 18-40 years working for ≥ 1 year. Workers with any chronic respiratory disease, chest deformity, or contraindication for spirometry were excluded. The unexposed group included males aged 18-40 years without history of dust exposure.

Data Collection

Permission was obtained from quarry owners and informed consent obtained from participants. Interviews were conducted privately at camps organized near the quarry units. Information on demographic factors, work history, smoking, and respiratory symptoms was collected using a modified standardized questionnaire. Participants then underwent clinical examination and spirometric measurements.

Variables

The primary outcome variable was lung function measured by spirometry. Predictor variables included exposure status, duration of dust exposure, smoking status, and type of quarry work. Confounding factors were

age, height, weight, smoking status, and prevalence of respiratory symptoms.

Spirometry Measurements

Spirometry was performed using RMS PFT machine. Parameters measured included forced vital capacity (FVC), forced expiratory volume at the end of 1st second (FEV₁), peak expiratory flow rate (PEFR), and FEV₁/FVC. Different occupational categories, including loaders, blasters, stone cutters, stone grinders, drillers, and supervisors, had their pulmonary function test parameters evaluated. To eliminate diurnal variation, the study was conducted every day at the same time. Abnormalities were categorized as restrictive, obstructive, or mixed pattern.

Ethics Approval

The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to data collection. Participation was voluntary with no incentives provided.

STATISTICAL ANALYSIS

Statistical analysis was performed using Jamovi software. Descriptive statistics were calculated. To compare pulmonary function tests between the exposed and unexposed groups, an unpaired t-test was conducted.^{5,6} The PFT of three groups (i.e., 1–5, 5–10, and >10 years of exposure to quarry dust) evaluated among the exposed population was compared using an ANOVA test.⁷ Pearson's correlation of duration of exposure in years with FVC, FEV₁, PEFR, and FEV₁/FVC of the exposed population was done. ANOVA test was done to compare the pulmonary function parameters among the various categories (loaders, blasters, stone cutters, stone grinders, drillers, and supervisors) of the exposed population. Smoking in packs among the population who were exposed to the dust was noted and simple linear regression was done for the length of exposure in years of different spirometry parameters before

multiple regression analysis.⁸ P-value ≤ 0.05 was considered statistically significant.

RESULT

Study Population Characteristics

The study included 200 male quarry workers (exposed group) and 200 unexposed males. The mean age was 29 years in both groups. Height, and weight were significantly lower in the exposed compared to unexposed group.

Exposure Characteristics

Among quarry workers, the mean duration of dust exposure was 6.4 years. Over 60% had 5-10 years of exposure. Loaders, drillers, and stone grinders together comprised over 50% of workers. More than 90% were current smokers with the majority smoking 1-5 pack years.

Respiratory Symptoms

Chronic respiratory symptoms were reported by only 4.5% of quarry workers compared to none in the unexposed group. Cough and phlegm production were the main symptoms.

Lung Function Parameters

All spirometric parameters were significantly lower in the exposed compared to unexposed group. The mean FVC was 2.27L in exposed and 3.24L in unexposed ($p < 0.001$). The mean FEV₁ was 1.99L in exposed and 3.05L in unexposed ($p < 0.001$). The FEV₁/FVC ratio was 88.8% and 93.3% in exposed and unexposed groups respectively ($p = 0.002$). The mean PEFR was 4.92L/sec in exposed and 8.13L/sec in unexposed groups ($p < 0.001$). (Table 1)

Effect of Years of Dust Exposure

There was a significant decline in FVC, FEV₁, and PEFR with increasing duration of dust exposure ($p < 0.001$). Workers exposed for >10 years showed the greatest reductions compared to the 1-5 years exposure group. The FEV₁/FVC ratio increased with longer duration of exposure. (Table 2) (Graph 1,2,3,4).

Effect of Type of Quarry Work

Among the study population, 22% were blasters, 19.5% were drillers, 19.5% were loaders, 19.5% were stone grinders, 13% were stone cutters, and 6% were supervisors. Loaders had the lowest FVC and FEV1 compared to other types of work. Drillers, stone grinders, blasters, and stone cutters also had significantly lower lung function than supervisors. The highest function was maintained among supervisors who have minimal dust exposure. (Table 3)

Effect of Smoking

Most quarry workers (92.5%) were current smokers. FEV1 showed the strongest correlation with smoking history after adjusting for dust exposure. Each additional pack-year of smoking was associated with a further decline in FEV1.

Predictors of Lung Function Decline

In multiple regression analysis, the duration of silica exposure was an independent predictor of reduced FVC and PEFR after adjusting for height, weight, smoking status, and pack years. Smoking history was an independent predictor of lower FEV1 along with silica exposure duration. For FEV1/FVC ratio, smoking had a lowering effect while silica exposure caused a restrictive pattern with elevated ratios. (Table 4-8)

In summary, stone quarry workers had significant lung function impairment of a restrictive nature compared to unexposed controls. The magnitude of decline in FVC, FEV1 and PEFR correlated with increasing years of silica exposure and higher dust levels based on type of work. Smoking contributed additional negative effects, especially on FEV1.

Table 1: Comparison of Pulmonary function test in exposed and unexposed groups studied.

PULMONARY FUNCTION TEST	EXPOSED POPULATION (n=200)	UNEXPOSED POPULATION (n=200)	P value
FVC(L)	2.27±0.49	3.24±0.46	<0.001**
FEV1(L)	1.99±0.54	3.05±0.54	<0.001**
PEFR(L/S)	4.92±2.24	8.13±1.48	<0.001**
FEV1/FVC%	88.77±19.29	93.26±6.58	0.002*

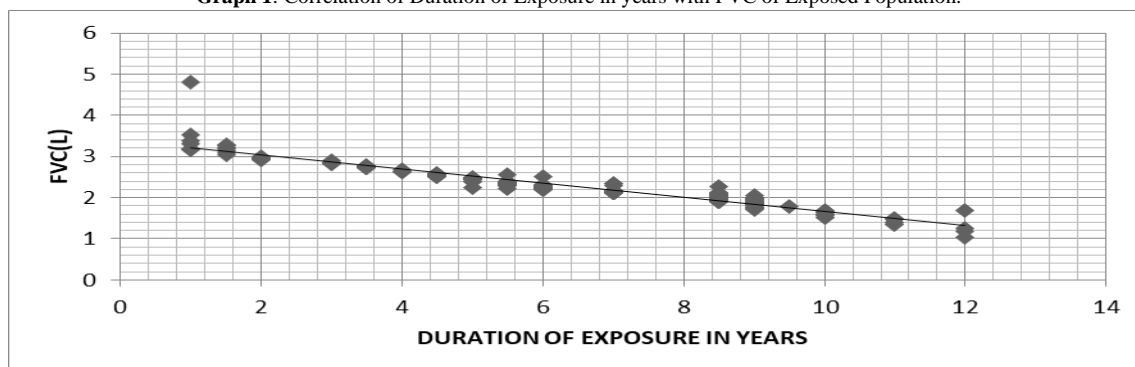
* Statistically significant, ** statistically highly significant

Table 2: Comparison of PFT with duration of exposure in years of three groups studied among the exposed population by ANOVA test.

PFT	Duration of exposure in years			P value
	1-5	5-10	>10	
FVC(L)	2.79±0.38	2.07±0.23	1.37±0.18	<0.001**
FEV1(L)	2.28±0.60	1.89±0.42	1.27±0.15	<0.001**
PEFR(L/S)	5.76±2.80	4.64±1.80	2.94±0.91	<0.001**
FEV ₁ /FVC%	82.62±22.09	91.56±17.60	93.92±8.71	0.006*

* Statistically significant, ** statistically highly significant.

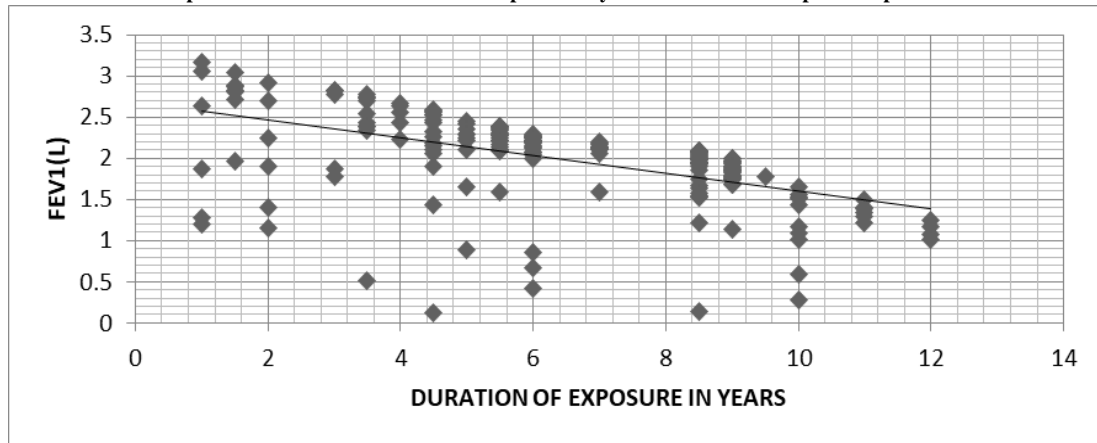
Graph 1: Correlation of Duration of Exposure in years with FVC of Exposed Population.



n=200, r= -0.86, p= 0.01

A significant negative correlation was seen between duration of exposure in years and FVC of exposed population.

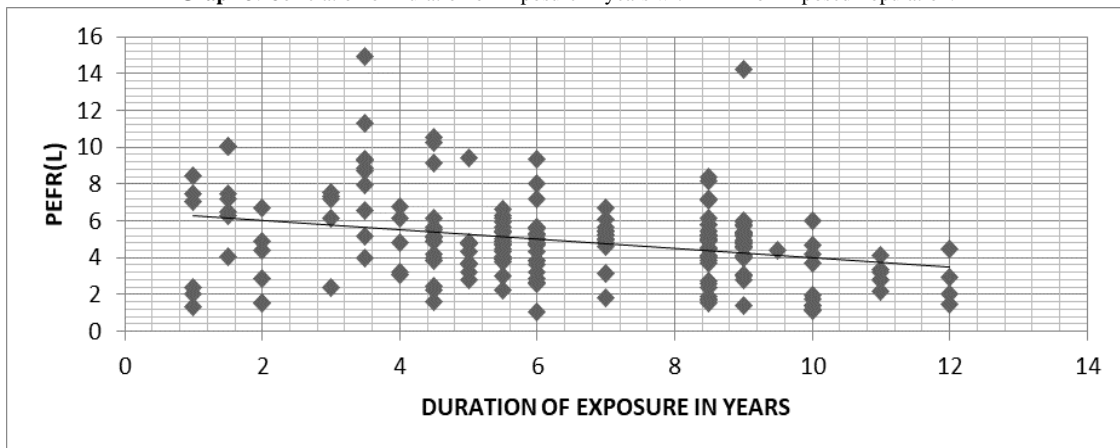
Graph 2: Correlation of Duration of Exposure in years with FEV₁ of Exposed Population.



n=200, r= -0.50, p=0.01

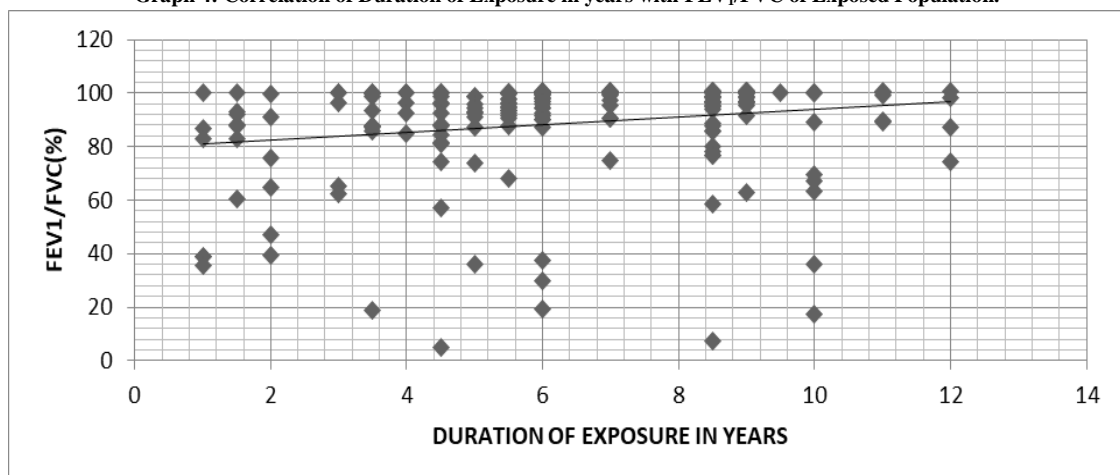
A significant negative correlation was seen between duration of exposure in years and FEV₁ of exposed population.

Graph 3: Correlation of Duration of Exposure in years with PEFR of Exposed Population.



n=200, r= -0.30, p=0.01

Graph 4: Correlation of Duration of Exposure in years with FEV₁/FVC of Exposed Population.



n=200, r= 0.17, p=0.05

Table 3: Comparison of the pulmonary function parameters among the various categories of exposed population by ANOVA test

Variables	Category						P value
	Blasters	Drillers	Loaders	Supervisors	Stone cutters	Stone grinders	
FVC(L)	2.45±0.1	2.23±0.08	1.65±0.22	3.27±0.5	2.84±0.19	2.01±0.07	<0.001**
FEV ₁ (L)	2.18±0.44	2.01±0.43	1.48±0.37	2.38±0.56	2.38±0.64	1.86±0.34	<0.001**
PEFR(L/S)	4.96±1.92	4.82±1.59	3.92±2.35	6.49±2.6	6.09±3.22	4.68±1.53	<0.001**
FEV ₁ /FVC%	89.21±17.88	90.74±19.28	90.17±18.71	74.55±19.8	84.44±23.23	92.54±16.81	0.060

** Statistically highly significant

Table 4: Simple linear regression for duration of exposure in years of various spirometric parameters.

	Regression coefficient	t value	Pvalue
FVC	-0.948	-42.074	p=0.000**
FEV ₁	-0.543	-9.089	p=0.000**
FEV ₁ /FVC	0.202	2.905	p=0.004*
PEFR	-0.307	-4.53	p=0.000**

* Statistically significant, ** statistically highly significant.

Table 5: Multiple regression of FVC with its predictors

Predictor variable	FVC(L) (Dependent variable)			
	Simple linear regression coefficient	Multiple linear regression coefficient	t value	p value
Duration of exposure in years	-0.948	-0.948	-42.074	0.000*
Smoking in pack years	-	0.044	1.965	0.051
Height	-	0.033	1.49	0.138

* Statistically highly significant.

Table 6: Multiple regression of FEV₁ with its predictors

Predictor variable	FEV ₁ (L) (Dependent variable)			
	Simple linear regression coefficient	Multiple linear regression coefficient	t value	p value
Duration of exposure in years	-0.642	-0.642	-18.907	0.000*
Smoking in pack years	-	-0.702	-20.96	0.000*
Height	-	-0.004	-0.063	0.949

* Statistically highly significant.

Table 7: Multiple regression of FEV₁/FVC with its predictors

Predictor variable	FEV ₁ /FVC (%) (Dependent variable)			
	Simple linear regression coefficient	Multiple linear regression coefficient	t value	p value
Duration of exposure in years	0.202	0.085	2.225	0.027
Smoking in pack years	-	-0.833	-21.881	0.000*
Height	-	-0.033	-0.861	0.39

* Statistically highly significant.

Table 8: Multiple regression of PEFR with its predictors.

Predictor variable	PEFR(L) (Dependent variable)			
	Simple linear regression coefficient	Multiple linear regression coefficient	t value	p value
Duration of exposure in years	-0.307	-0.336	-5.016	0.000
Smoking in pack years	-	-0.205	-3.07	0.002
Height	-	0.042	0.639	0.524

DISCUSSION

One of the oldest occupational diseases known to man is silicosis, which was initially reported in India in 1935 at the Kolar Gold Fields by Dr. Krishnaswami. This cleared the path for innovative research and the creation of

corporate policies for worker protection. However, silicosis continues to affect people all over the world in developed and developing countries. The latest estimate is that 3 million people in our country are exposed to silica that is without including many more in industries like construction.⁹

An important group of workers exposed to this highly toxic dust belong to those in the quarry industry and they belong to the unorganized sector. Inhalation of silica leads to adverse respiratory effects like chronic bronchitis which further leads to the development of silicosis. Silicosis is a predisposing factor for the development of pulmonary tuberculosis and lung cancer.^{10,11} It must be stressed that silicosis cannot be treated and hence the primary need is prevention or at least early detection.

Spirometry results of the quarry workers in our study showed pulmonary dysfunction with FVC, FEV₁, PEFR, and FEV₁/FVC values being statistically lower than the unexposed group. As mentioned earlier, quarry workers have much lower FEV₁ and FVC, although the FEV₁/FVC ratio was above 70%, indicating a restrictive anomaly that is also observed by many other people.^{12,13}

Quarry workers' PEFR has significantly decreased, which may be related to increased dust exposure. The large caliber airways play an important role in determining peak flow which mainly depends on expiratory muscle strength. According to a study done on employees at sandstone quarries, the duration of exposure has an impact on the lungs' peak expiratory flow rate.⁸

Among the quarry workers we studied, 62.5% were exposed to dust for 5-10 years, 32.5% of them were exposed to dust for 1-5 years and only 5% of them were exposed to dust for more than 10 years. It was seen that an increase in duration of exposure to dust in years decreased PFT and there was a significant negative correlation between duration of exposure to dust and pulmonary function. In our study pulmonary function impairment was seen within 5 years of exposure. Post hoc Bonferroni test revealed that lung impairment was significantly higher among the quarry workers exposed to dust for >10 years and 5-10 years in comparison with 1-5 years. Our study corroborated with many studies where the pulmonary function tests declined with

increasing duration of exposure to dust. A study in Nigeria showed a significant decrease in FVC and FEV₁ among the quarry workers of the stone-crushing industry exposed to dust.¹¹ Another study done on stone crushers found that PFT bears a relationship with duration of exposure, as the duration of exposure increases the PFT goes on decreasing.¹⁴ PFT on quarry workers in Nagpur showed impairment after 15 years and they document that the cumulative dust exposure recorded among them was less.¹⁵ A study on stone cutters of an Iranian factory showed impairment of lung function with >20 years of exposure to dust.¹⁶ PFT on the quarry workers in Chennai revealed impairment of lung functions among those exposed to dust for >15 years.¹⁷ A study done by Chattopadhyay among stone-crushing workers found that there was a significant decrease in FVC, FEV₁/FVC ratio with the increase in the duration of exposure.¹⁸ Another study by Johny on construction workers found an increase in lung impairment with increase in duration of exposure to dust in years.⁶

The quarry workers were further categorized based on their work as blasters, drillers, loaders, stone cutters, stone grinders and supervisors depending on their job description, as the quantity of dust exposure varied with their job. Lung functions were significantly lower among all the categories except supervisors. This may be attributed to the fact that supervisors were exposed to less cumulative dust. Loaders were affected the most, which may be due to high cumulative dust exposure and also longer duration of exposure among them. Stone grinders were affected next with significantly lower FVC and FEV₁ in comparison with blasters, stone cutters and supervisors. FVC of drillers was significantly lower in comparison with blasters and supervisors. Among the various categories, blasters and stone cutters were found to be affected the least. It was also observed that there was a decrease in FVC as well as FEV₁ with FEV₁/FVC ratio that was normal or increased among the different

categories suggestive of restrictive type of lung disease. Most studies assessed quarry workers as whole and did not categorize them. A study in Iran showed that hammer drillers were more affected due to high concentration of dust exposure, whereas, subjects exposed to dry-cutting a relatively new, artificial, decorative stone product with high crystalline silica content, had moderate-to-severe restrictive lung disease.^{19,13} In another study in Iranian factory workers they showed that stone grinders were affected more as the cumulative dust exposure among them was higher in comparison with the stone cutters, which was consistent with our study.¹⁶ The Nagpur study did not show any difference between stone cutters and grinders and that may be because of the very low cumulative dust exposure recorded.¹⁵

Smoking is a risk factor for the development of lung impairment. In our study, 92.5% of the quarry workers were smokers of which the majority of them (78%) smoked 1-5 pack years and 14.5% of them smoked more than 5 pack years. 7.5% were found to be non-smokers. In our study smoking was found to be an important contributor to the decrease in FEV₁. Results from earlier studies have also confirmed that lung function values have decreased significantly more in those who have been exposed to both silica and tobacco than in people who have only been exposed to one of them.^{20,21} Though smoking can change the pattern from restrictive pulmonary disease to obstructive type, in our study they showed a restrictive type of pulmonary dysfunction.²² Regression analysis was done to know the independent risk factor of the restrictive type of lung disease seen among the exposed population. Simple linear regression for duration of exposure in years of various spirometric parameters was done and then, multiple regression analysis was done to know if smoking was a confounding factor. Duration of exposure and smoking was found to be predisposing factors for a decrease in lung functions, similar to one of the studies done in Tamil Nadu.²³ Duration

of exposure as well as smoking was found to be predisposing factors for a decrease in FEV₁. After adjusting for smoking, the duration of exposure in years was found to be an independent risk factor for a decrease in FVC, PEF_R, and an increase in FEV₁/FVC ratio suggesting that the duration of exposure in years is an independent risk factor for the restrictive type of lung disease among the quarry workers.

A modified prevalidated respiratory questionnaire was used to assess the chronic symptoms of pulmonary dysfunction if any, on the quarry workers and unexposed population. 95.5% of the quarry workers did not complain of any respiratory symptoms like chronic cough, phlegm production, or breathlessness in contrast to the Nigerian study on quarry workers where they quoted occasional cough as high as 40.7% and blood-stained sputum of 6.5%.¹¹ This contrast may be due to the fact that silicosis is known to present in three forms, acute form, accelerated form, and chronic form. In the chronic form, the patients are known to be symptomless for 10-20 years.^{16,24} As 95% of our exposed group had an exposure to dust of less than 10 years they may be oligosymptomatic. The other plausible explanation may be due to the fear of losing their livelihood or repercussions from the management as they belonged to the unorganized sector. Quarry workers in our study exposed to dust had a significant reduction in pulmonary function parameters with a restrictive pattern but the questionnaire result mainly was negative showing that the questionnaire was an inadequate screening tool.

The quarry workers described that they typically worked without any personal respiratory protection for an average of 10 hours each day without any dust suppression (e.g., wet cutting as opposed to dry cutting or efficient local ventilation). The results of our study were shared and discussed with the quarry workers with regard to their pulmonary function, duration of exposure to dust, and smoking habits. An attempt was made to educate the workers about healthy

lifestyles, the necessity to stop smoking, the usage of protective gear, and regular medical examinations. They were also provided with masks as one of the steps of occupational health measures.

Management and supervisors were educated on the importance of measures such as pre-employment screening, use of suitable personal protective equipment (PPE), education, training and supervision of workers, environmental monitoring, and health surveillance.

CONCLUSION

The lung functions of quarry workers were significantly reduced as compared to that of the unexposed group. Therefore, this study provides important evidence that stone quarry workers in South India develop restrictive lung function impairment that worsens with increasing years of silica exposure. Lung impairment was more among the loaders followed by stone grinders, drillers, blasters, and stone cutters showing that cumulative dust exposure was a contributing factor. The high smoking prevalence likely exacerbates respiratory effects. The respiratory questionnaire was ineffective as a screening tool to assess lung impairment in quarry workers. PFT analysis served as a useful tool in the early diagnosis of lung impairment among quarry workers. The results highlight the urgent need for improved dust control measures, regular lung function surveillance, and smoking cessation programs in this at-risk working population.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: It gives me joy to express my gratitude to everyone who contributed to the success of our research. I sincerely appreciate every subject's willingness to go through the necessary procedure, and I want to thank them all from the bottom of my heart. I appreciate all of Dr. Achuth K.S.'s help in getting me to

the quarry site where I needed to collect data.

Source of Funding: None

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Yadav SP, Anand PK and Singh H: Awareness and Practices about Silicosis among the Sandstone Quarry Workers in Desert. Ecology of Jodhpur, Rajasthan, India. *J Hum Ecol.* 2011, 33:191-196. 10.1080/09709274.2011.11906359
2. Kiran Kumar CH, Mallikarjuna Reddy N, Sharan B Singh M: Deterioration of pulmonary function in stone quarry workers. *Biomedical Research.* 2014, 25:261-266.
3. Deshmukh A. A, Kulkarni N. P, Dhattrak S. V, Subroto, Nandi S: S. Assessment of Occupational Dust and Silica Exposure in Indian Stone Mining and Crushing Unit- A Case Study. *Curr World Environ.* 2017, 12:12944/CWE.12.3.17
4. Sheikh JA, Khan ZA, Khan T, Chowdhary S: Pulmonary function among stone quarry workers in India: The effect of duration of exposure, smoking status and job profile on pulmonary function tests. *J Health Soc Sci.* 2018, 3:137-46.
5. Smilee JS, Ajay KT, Dhanyakumar G, Prabhu RN, Vivian ST. Effect of occupational exposure to dust on pulmonary function in workers associated with building demolition. *Biomedical Research.* 2011, 22:241-247.
6. Johny S, Ajay KT, Dhanyakumar G, Raj PN, Samuel VT: Dust exposure and lung function impairment in construction workers. *J Physiol Biomed Sci.* 2011, 24:9-13.
7. Rajnarayan RT, Raj N, Bhupendra DP, Ishwar SM, Habibullah NS: Spirometric measurements among quartz stone ex-workers of Gujarat, India. *J Occup Health.* 2003, 45:88-93. 10.1539/joh.45.88
8. Mathur ML, Dixit AK. A study of forced vital capacity and its predictors among the sand stone quarry 11 of 12 workers. *Indian J Physiol Pharmacol.* 1999, 43:347-54.
9. Jindal SK: Silicosis in India: Past and Present. *Curr Opin Pulm Med.* 2013, 19:163-168. 10.1097/MCP.0b013e32835bb19e
10. Park K: Occupational health In: Park's textbook of preventive and social medicine .

- Jabalpur: M/s Banarsidas Bhanot. 2007:608-610.
11. Nwibo AN, Ugwuja EI, Nwambeke NO, Emelumadu OF, Ogbonnaya LU: Pulmonary Problems among Quarry Workers of Stone Crushing Industrial Site at Umuoghara, Ebonyi State, Nigeria. *Int J Occup Environ Med.* 2012, 3:178-185.
 12. Mashaallah A, Ali N, Morteza N, Ghavamedin A: Silicosis among Stone-Cutter Workers: A Cross-Sectional Study. *Tanaffos.* 2012, 11:38-41.
 13. Mordechai RK, Paul DB, Elizabeth F: Anat Al, Alexander G, Nader AR et al. Caesar stone silicosis: disease resurgence among artificial stone workers. *Chest.* 2012, 1:22. 10.1378/chest.11-1321
 14. Sachin BR, Smita RS: Effect of duration of exposure to silica dust on lung function impairment in stone crusher workers of Marathwada region. *NJIRM.* 2013, 4:23-38.
 15. Ghotkar VB, Maldhure BR, Zodpey SP: Involvement of lung and lung function tests in Stone quarry workers. *Ind J Tub.* 1995, 42:155-160.
 16. Bahrami AR, Mahjub H: Comparative study of lung function in Iranian factory workers exposed to silica dust. *Eastern Med Health J.* 2003, 9:390-398.
 17. Subhashini AS, Satchidhanandam N: Maximal expiratory flow volume curve in quarry workers. *Indian J Physiol Pharmacol.* 2002, 46:78-84.
 18. Chattopadhyay BP, Gangopadhyay PK, Bandopadhyay TS Alam J: Comparison of pulmonary function test abnormalities between stone crushing dust exposed and non-exposed agricultural workers. *Environ Health Preventive Med.* 2006, 11:191-198.
 19. Farideh G, Mohammad-Ali B, Manouchehr S: Evaluation of Workers' Exposure to Total, Respirable and Silica Dust and the Related Health Symptoms in Senjedak Stone Quarry, Iran. *Industrial Health.* 2004, 42:29-33. 10.2486/indhealth.42.29
 20. Hnizdo E: Loss of Lung Function associated with exposure to Silica dust and with smoking and its relation to disability and Mortality in South African Gold miners. *Br J Industr Med.* 1992, 49:472-479.
 21. Hnizdo E, Baskind E, Sluis-Cremer GK: Combined Effect of Silica dust exposure and Tobacco Smoking on the Prevalence of Respiratory impairments among Gold miners. *Scand J Work Environ Health.* 1990, 16:411-422.
 22. Sivanmani K, Rajathinakar V: Silicosis in Coimbatore district of Tamil Nadu: A passive surveillance study . *Indian J Occup Environ Med.* 2013, 17:25-28. 10.4103%2F0019-5278.116370
 23. Arumugam E, Rajkumar P, Dhanaraj B, Govindasamy E, Jaganathasamy N, Mathiyazhakan M.: Determining pulmonary function and the associated risk factors among stone quarry workers in a suburban area of Chennai, Tamil Nadu, India. *Lung India.* 2021, 38:558-63. 10.4103%2Flungindia.lungindia_63_21
 24. WHO (ed): Hazard Prevention and Control in the Work Environment: Airborne Dust. 1999, 1-224.

How to cite this article: Sindhu R, Karthiyanee Kutty, Vinutha Shankar MS. Effects of prolonged silica exposure on pulmonary function among stone quarry workers in South India. *Int J Health Sci Res.* 2023; 13(10):322-331. DOI: [10.52403/ijhsr.20231044](https://doi.org/10.52403/ijhsr.20231044)
