Silica Exposure and Effect on Peak Expiratory Flow: Slate Pencil Workers' Study

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BACKGROUND: Peak expiratory flow (PEF) is a spirometric test that detects obstructive changes in the respiratory tract; has good correlation with the FEV_1; and is much less expensive, simpler, and easier to perform under field conditions than FEV_1. Chronic silicosis is also known to have obstructive features in advanced stages. Thus, this study was performed to assess the effect of silica exposure on PEF and the factors related to it. METHODS: The present study was carried out among 193 slate pencil cutting workers of Multanpura village of Madhya Pradesh, India. An interview technique was used to record demographic characteristics and occupational history on a predesigned form, which included a questionnaire regarding occupational history and silica-related respiratory morbidities. This was followed by a complete medical examination and measurement of PEF using a spirometer. RESULTS: The mean age was 43.35 ± 11.31 y, and the mean duration of exposure was 18.72 ± 9.33 y. In the present study, PEF was found to be significantly reduced in those age ≥40 y, those who were female, those having duration of exposure >10 y, and those having respiratory morbidity, whereas the reduction in PEF was statistically nonsignificant for smokers. CONCLUSIONS: Higher age, female sex, higher duration of exposure, and respiratory morbidity were found to be important correlates of PEF. *Key words: silica; silicosis; PEF; slate pencil cutters; India.* [Respir Care 2016;61(12):1659–1663. © 2016 Daedalus Enterprises]

Introduction

Dust exposure in the workplace is still an important occupational health problem for those working in a dusty environment. Exposure to free silica by inhalation and its retention in the lungs results in a fibrotic lung disease known as silicosis.[1] Despite adequate knowledge of the cause of this disorder (ie, respiratory exposure to silica-containing dusts), this serious and potentially fatal occupational lung disease remains prevalent throughout the world. The prevalence of the disease varies greatly in different regions of the world. Whereas the developed nations have successfully brought down the occurrence of silicosis, in India, the exact magnitude of the problem is still not known. The situation is further aggravated by a considerable proportion of workers working in the varied unorganized sectors where they are exposed to silica dust without any preventive measures. Occupations that expose workers to silica dust include sandstone quarries, the agate industry, the slate pencil cutting industry, the ceramic and pottery industry, and many more.

In Madhya Pradesh, slate pencil workers of Multanpura are a group of unorganized workers. Slate pencils are made from a type of sedimentary rock known as shale,[2] which is composed of mud that is a mixture of clay minerals (kaolinite, montmorillonite, and illite) and small quantities of other minerals, especially quartz and calcite. The ratio of clay to the other minerals gives the shale its color. Shale from which slate pencils are made is light gray in color. Slate pencils in some regions are made from soft soapstone, which is a metamorphic rock, composed predominantly of talc.

These workers bring the slate stones from the slate mines and then cut it with the help of a rotating saw. This process generates dust. Some proportion of this dust is vacuumed up by the indigenously developed control device contain-

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ing an exhaust pump at the site of cutting. This vacuumed dust is then released into the ambient air, thereby exposing the community to silica dust via a polluted environment. Employment in the slate pencil cutting is informal; thus, workers do not come under the purview of social security schemes meant to protect worker health and welfare. As a result of this, fatal diseases, such as silicosis, often remain undetected in these workers.

The dust-related occupational respiratory diseases not only cause damage to the lung but also result in impairment in lung volumes and flows. Ironically, this impairment in lung volumes and flows is often noticed in the advanced stages of the disease, with much of the lung tissue already being damaged. Thus, to detect the impairment early and to assess the progress of such impairment, it is recommended to measure the lung volumes and flows periodically.

Peak expiratory flow (PEF) is a pulmonary flow reflecting obstruction in the airways. It can be simply measured using equipment such as the Mini Wright PEF meter (Clement Clarke, UK), which are inexpensive and portable devices and serve a variety of functions.[3-5] In general, FEV_1 measurements by spirometry are preferred because they are much more reproducible. However, spirometry is not widely available, and the technical pitfalls of performing spirometry frequently limit its usage, especially at a primary care level.[6] Using PEF measurement is more economical and much more widely available; therefore, it is proposed as an alternative to spirometry.[7,8] Further, earlier studies have shown that the correlation coefficients between percent predicted PEF and percent predicted FEV_1 are moderate to good, ranging from 0.5 to 0.9.[9,10] However, the PEFs vary individually and are dependent on multiple factors, such as cigarette smoking, the type of dusts involved in the exposure (mixed vs pure), the dose of dust and duration of exposure, and the presence other pulmonary diseases, such as tuberculosis.[11] Thus, it is difficult to arrive at definite conclusions about the changes in PEF in workers with silicosis. Also, limited numbers of studies are available on the effect of silicosis or silica exposure on the alterations in PEF. With this background, the present study was carried out among silica-exposed slate pencil cutters to assess the changes in PEF and its correlates.

QUICK LOOK

Current knowledge

Silica exposure results in fibrotic lung disease known as silicosis. Silicosis results in a restrictive pattern on spirometry.

What this paper contributes to our knowledge

The restrictive pattern of silicosis was also combined with the obstructive patterns in some cases. The changes in PEF, which is a good correlate of FEV_1, depended on factors such as age, duration of exposure, and smoking.

Methods

The present study was designed as a cross-sectional study. One hundred ninety-three slate pencil cutters of Multanpura village in the Western zone of India were included. All of the workers were involved in cutting the shale stone chips into slate pencils using a power-operated rotating saw. The institutional ethics committee approved the study, and informed written consent was received from each participant before initiating the data collection. The demographic, occupational, and clinical details of the participants were recorded by a one-to-one interview method on a predesigned pretested questionnaire containing questions regarding age, sex, educational status, socioeconomic status, process of slate pencil cutting in which employed, duration of employment, protective devices used, and symptoms. The International Labour Office Classification of Pneumoconiosis 2000 edition was used to classify the chest radiographs as findings suggestive of silicosis and/orsilicotuberculosis. The PEF of the subject was measured using a Spirovit SP-10 spirometer (Maker Schiller AG, Switzerland) just after the completion of work for the day. After calibrating the spirometer according to the procedure given in the catalog, 3 readings of PEF of each subject were taken. The PEF test is an effort-dependent test, and it was assumed that the participant cooperated to the maximum in the highest reading; thus, the reading showing the highest flow was recorded and used for further analysis. On the basis of the occupational history, symptoms, and chest radiographic findings, final diagnosis of silica-related respiratory morbidities (ie silicosis and silicotuberculosis) was done. For analysis of the factors associated with reduction in PEF, factors such as age, smoking habits, duration of exposure, and respiratory morbidity were arbitrarily dichotomized and analyzed for the absolute values of PEF. Statistical analysis was carried out using the statistical software package SPSS 15.0 (SPSS, Chicago, Illinois) and included calculation of proportion and percentages and application of tests of significance, such as one-way analysis of variance, *t* test, and chi-square test.

Results

Table 1 shows the distribution of study subjects according to demographic characteristics. One hundred

Table 1. Distribution of Study Subjects According to Demographic Characteristics

Characteristics	n (%)
Age, y	
≤30	22 (11.4)
31–40	79 (40.9)
41–50	56 (29.0)
≥51	36 (18.7)
Sex	
Male	82 (42.5)
Female	111 (57.5)
Marital status	
Single	8 (4.1)
Married	117 (60.6)
Divorced	1 (0.5)
Widowed	67 (34.7)
Educational status	
Illiterate	163 (84.5)
Primary school	17 (8.8)
Middle school	13 (6.7)

Table 2. Mean Observed Peak Expiratory Flow According to the Dichotomized Variables

Factors	n	Mean Observed PEF	SD	P
Age, y				
≤40	101	4.82	2.08	<.001
>40	92	3.05	1.43	
Sex				
Male	82	4.90	2.20	<.001
Female	111	3.29	1.51	
Smoking habits†				
Smokers	42	4.82	2.13	.068
Non-smokers	40	4.99	2.29	
Duration of exposure, y				
≤10	50	5.10	2.32	.003
>10	143	3.58	1.72	
Respiratory morbidity				
Present	111	3.29	1.81	.042
Absent	82	4.90	1.88	

† Includes only males because there were no female smokers.
PEF = peak expiratory flow

ninety-three subjects included 82 (42.5%) males and 111 (57.5%) females. The majority of the subjects were <45 y old (67.9%). The mean age for males was 40.3 ± 11.7 y, whereas that for females was 45.6 ± 10.5 y, and for the whole group, it was 43.4 ± 11.3 y. Similarly, the mean duration of exposure for males was 17.7 ± 9.7 y, whereas that for females was 19.5 ± 9.0 y, and for the whole group, it was 18.7 ± 9.3 y. Marital status indicated that 67 subjects (34.7%) were widows/widowers, which included 58 (86.6%) females and 9 (13.4%) males. The majority of the subjects were illiterate. Further, it was observed that no worker was using any personal protective devices to safeguard against dust.

Table 2 describes the mean observed PEF according to the dichotomized variables. For dichotomizing the smoking habits, the ex-smokers (those who had quit smoking ≥1 y previously) were combined with current smokers. Unadjusted analysis revealed that absolute values of PEF were lower for the categories: age ≥40 y, female, those working for >10 y in the present occupation, and those having respiratory morbidity, such as silicosis, silicotuberculosis, and tuberculosis.

Table 3 shows the mean observed PEF according to the presence or absence of respiratory morbidity after adjusting for the study factors (ie, age, sex, duration of exposure, and smoking habits). It can be observed that the mean observed PEF was lower in those having respiratory morbidity as compared with those free from any respiratory morbidity. However, the difference was found to be statistically nonsignificant.

Discussion

In the present study, the mean PEF was found to be 3.97 ± 1.99 L/min. When the absolute values of PEF were analyzed against dichotomized variables, PEF was statistically significantly lower in those age >40 y as compared with those ≤40 y, in females as compared with males, in those who were working for >10 y in their present occupation as compared with those who were working for ≤10 y, and in those having silica-related respiratory morbidity, such as silicosis, silicotuberculosis, and tuberculosis, as compared with those who were free from these respiratory morbidities. Although PEF was lower in smokers as compared with non-smokers, the difference was found to be statistically nonsignificant.

Higher PEF in the younger workers may be attributed to good muscle contraction, which helps in expelling a greater portion of inhaled air. As age advances, chest muscle contraction strength decreases,[12,13] which may have resulted in the reduction in PEF with increasing age in the present study. This can be further substantiated by the fact that studies have shown that increasing the strength of respiratory muscles through exercise results in an increase in PEF.[14-16]

The chest muscles of females are physiologically weaker than that of males, which result in lower PEF among females. Further, in addition to biologically weaker respiratory muscles, females are disadvantaged by multiple noxious exposures resulting in respiratory insult, such as indoor air pollution through the use of dirty fuels[17] (eg, cow dung, wood, grain husks, etc) yielding high quantities of air pol-

Table 3. Peak Expiratory Flow According to Respiratory Morbid Conditions After Adjusting for Other Study Variables

Respiratory Morbid Conditions	Peak Expiratory Flow, L/min										
	Age Group, y*				Sex†		Duration of Exposure, y‡			Smoking Habits§	
	≤30	31–40	41–50	≥51	Male	Female	<10	10–20	≥20	Non-smoker	Smoker
Normal	6.07 ± 1.89	5.29 ± 1.59	3.78 ± 1.38	2.90 ± 1.36	5.58 ± 2.1	4.25 ± 1.37	5.29 ± 2.14	5.03 ± 1.51	2.87 ± 1.06	6.02 ± 2.16	5.09 ± 1.99
With morbidity	6.40 ± 0.64	3.76 ± 2.09	3.01 ± 1.47	2.63 ± 1.28	4.26 ± 2.12	2.71 ± 1.29	4.74 ± 2.63	3.09 ± 1.58	2.94 ± 1.37	4.59 ± 2.26	3.86 ± 1.9

Data are mean ± SD.
* $P = .88$.
† $P = .76$.
‡ $P = .84$.
§ $P = .76$.

lutants and exposure to dust-containing silica at the workplace that is also known to affect the respiratory system and pulmonary function.[18,19] The lower PEF in females in the present study can also be partly attributed to their significantly higher age as compared with the males.

PEF among smokers was lower as compared with that of non-smokers, but the difference was statistically nonsignificant. This could be due to the small sample of current smokers and underreporting by study subjects. Even combination of the ex-smokers with smokers did not result in a significant difference in the mean PEF between smokers and non-smokers, which can be attributed to occasional smoking by the ex-smokers. However, some studies have shown significantly lower PEF among smokers than non-smokers.[20]

Irritation of upper respiratory mucosa due to dust or other toxicants causes hypertrophy of the mucosal lining. This results in the increased secretion of mucus and the formation of mucosal plugs, which causes obstruction to the exhaled air.[19,20] Thus, in the present study, subjects who were exposed to dust for >10 y were found to have lower PEF than those who were exposed for ≤10 y. Moreover, a higher proportion (65%) of those exposed for >10 y had respiratory morbidity as compared with those exposed for ≤10 y (34%), and the difference was found to be statistically significant ($P < .001$).

Although silica-related respiratory morbidities among the exposed population are restrictive in nature, they also result in reduced PEF. Hypertrophy of mucosal cells and formation of mucosal plugs due to irritation of upper respiratory mucosa resulting in obstruction of exhaled air could be a possible reason for this. Both dust exposure and smoking result in a similar mechanism. Earlier studies have demonstrated similar association between PEF and respiratory morbidity.[21]

Further, 2-way analysis of variance was done to study the effect of respiratory morbid conditions while adjusting for age, sex, duration of exposure, and smoking habits. Absolute values of PEF were reduced among the subjects suffering from respiratory diseases, such as silicosis, silicotuberculosis, and tuberculosis, as compared with those without respiratory disease when adjusted for age, sex, duration of exposure, and smoking, although statistically nonsignificant ($P > .05$).

Thus, in the present study, the mean PEF among slate pencil cutters was found to be 3.97 ± 1.99 L/min. These slate pencil cutters who are exposed to free silica have reduced PEF, and it can be attributed mainly to respiratory disorders. The other epidemiological factors found to be significantly associated with reduced absolute values of PEF include age >40 y, female sex, and dust exposure for >10 y, whereas smoking was nonsignificantly associated with reduction in PEF. However, comparison with a suitable control group would have resulted a clearer interpretation, and this is a limitation of the study. Efforts were made to reduce this limitation by internal comparison.

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