Respiratory symptoms and ventilatory function among granite workers working in quarries installed with mechanical crushers in and around Kandy Municipality limits

P Jayawardana [1], S Tennakoon [2], V Bandara [3]

Abstract

Objectives: To compare the presence of selected respiratory symptoms among granite workers with a control group and to assess ventilatory function (VF) and radiological changes in the lungs of granite workers.

Methods: A cross-sectional analytical study was conducted on workers employed in the granite quarries installed with mechanical crushers in and around the Kandy Municipality limits. The control group comprised persons accompanying patients to the outpatient department of a tertiary care hospital. The respiratory symptoms were compared using an interviewer administered questionnaire. Only granite workers were subjected to spirometry and chest radiography. *Forced vital capacity (FVC), forced expiratory volume in the first second of FVC* and *peak expiratory flow rate* were assessed. The observed values of above were compared with predicted normal values. Chest radiographs were read by two radiologists conforming to ILO classification of radiographic appearances.

Results:

There were 51 granite workers and 51 controls. A higher proportion of granite workers had chronic cough (8%; n=4), and phlegm (16%; n=8) of ≥3 months duration and chronic bronchitis (16%; n=8) in comparison to the control group (2% [n=1], 6% [n=3] and 8% [n=4] respectively) but the differences were statistically not significant. A significantly higher proportion in the control group had dyspnoea (45%; n=23) and at least a single respiratory symptom (55%, n=28) in comparison to the granite workers (10% [n=5] and.31% [n=16] respectively).

The observed values of the three respiratory indices were significantly lower than the predicted norms. Twenty four (47%) had a restrictive type and one (2%) an obstructive type of ventilatory impairment. None had radiological evidence of silicosis or tuberculosis.

Conclusions:

Ventilatory function of granite workers were affected significantly. Proportions with cough and phlegm of equal or more than three months duration and chronic bronchitis were higher among granite workers even though statistical significance was not reached. Proportions with dyspnoea and at least one respiratory symptom was significantly less among granite workers. There was no radiological evidence of silicosis or tuberculosis. Installation of exhaust ventilation, use of industrial masks and limitation of exposure time is recommended.

Key Words:

Granite workers, Ventilatory impairment, Respiratory symptoms

Introduction

Granite is a mixture of quartz (silicon dioxide), felspar and other minerals (1). The granite industry in Sri Lanka is over 2000 years old (1). Stone statues, pillars and inscriptions of ancient Sri Lanka bear evidence to this. Presently granite is used on a large scale for building and road construction work.

Granite occurs in rock form, and dynamite is used to blast the rocks where large fragments are separated out and these are further broken into smaller pieces according to the requirements. This was usually done manually with the help of a hammer. In some of the large quarries the manual process has been mechanised now with the installation of crushers. The use of crushers results in the release of large amounts of dust into the atmosphere where the workers are at risk of inhaling it.

Exposure to quartz or silica dust can lead to the development of chronic respiratory symptoms such as cough, phlegm and dyspnoea. In addition chronic exposure can lead to silicosis which is a form of pneumoconiosis that gives rise to fibrosis of the lungs

1. Consultant Community Physician and Senior Lecturer, Department of Public Health University of Kelaniya, Sri Lanka.
2. Lecturer, Department of Community Medicine , Faculty of Medicine, Peradeniya
3. Consultant Pediatrician, Base Hospital, Matale.

leading to respiratory failure. This is generally progressive and removal from exposure will not reverse the condition. Although the granite industry has been in existence for several years, silicosis (1) is not a common condition in Sri Lanka. Manual chiselling does not generate large quantities of dust and the low prevalence of silicosis may be attributed to it, in combination with the open environment they work in, unlike in temperate climates.

The objective of the study was to compare the presence of selected respiratory symptoms among granite workers with a control group and to assess ventilatory function (VF) and radiological changes in the lungs of granite workers employed in quarry sites installed with mechanical crushers.

Methodology

A cross sectional analytical study was conducted. The quarries fitted with mechanical crushers in and around the Kandy Municipality limits, were identified and all the workers employed at the crushers at these quarries, irrespective of the duration of service, were included in to the study.

The control group consisted of people accompanying patients to the outpatients' department of the Teaching Hospital, Peradeniya who were either unemployed, or employed in occupations not associated with specific dusts, fumes and gases. In order to ensure a similar socioeconomic background, the occupations selected were limited to health care minor staff, small scale traders, labourers, office support staff, and transportation workers. The unemployed recruited were from families with a similar employment background or those who have retired from similar occupations. Selection of controls was limited to the same age range and sex distribution as the granite workers.

The respiratory indicators (RI) studied were the forced vital capacity (FVC), forced expiratory volume in the first second during expiration ($FEV_{1.0}$) and the peak expiratory flow rate (PEFR) using an electronic spirometer which conformed to the specifications of the American Thoracic Society (3). The technique of taking a deep breath followed by rapid and continuous exhalation into the spirometer was demonstrated to the research participants by an experienced technician. They were allowed a minimum of three practice blows. Three readings were obtained once they mastered the technique. The highest reading out of the two which had a variation of less than 5% was considered as final. The observed values of RI were compared with the predicted normal values computed using the regression models developed for the Sinhalese by Udupihilla (4). The type of ventialtory impairment (VI) was assessed as described by.Gildea *et al* (5).

An interviewer administered questionnaire was used to assess details of the current and previous occupations, presence of respiratory symptoms (2) and smoking status. The granite workers were subjected to normal sized postero-anterior chest radiography and the readiographs were read by two experienced radiologists using the International Labour Office classification system. Only the questionnaire on respiratory symptoms was administered to the control group as it was not possible to carry out spirometry due to logistical constraints and chest radiography owing to ethical considerations.

The respiratory symptoms includes were presence of cough and phlegm, dyspnoea, and asthma. Dyspnoea was defined as shortness of breath when walking with other people at an ordinary pace on level ground. Chronic bronchitis was defined as presence of either cough or phlegm or both over a duration of three or more months per year, for two or more consecutive years (6).

Statistical analysis consisted of Student T test for quantitative data and the chi square test for qualitative data. A probability of less than 0.05 was considered as significant.

Ethical clearance for the study was obtained from the Ethical Review Committee of the Faculty of Medicine, Peradeniya, Sri Lanka.

Results

A total of 51 granite workers and 51 controls were included in the study. The response rate among the granite workers was 100%. The 51 controls who were purposively selected consisted of 42 males (84%) and 8 females (16%), the proportions which were same as for granite workers. The mean age of granite workers was 31.6 (SE = 1.7) years and that of the control group 35.7 (SE = 1.7) years, the difference of which was not statistically significant. Thirty three (64.7%) among controls were employed. The duration of service among granite workers ranged from 0.2 – 20 years with a median of one year (Table 1).

The proportion with cough (8%; n=4) and phlegm (16%; n=8) with a duration of three or more months and chronic bronchitis (14%; n=7) was higher among granite workers than among controls (2% [n=1], 6% [n=3] and 8% [n=4] respectively) but none of the differences were statistically significant. The proportion with cough (18%; n=9) and

phlegm (20%; n=10) of less than 3 months duration, dyspnoea (45%; n=23), and any single respiratory symptom (65%; n=33) were higher among the control group (Table 2) in comparison to granite workers (8% [n=4]; 12% [n=6], 10% [n=5] and 37% [n=19]), of which, dyspnoea (OR=0.1; 95% CI: 04 –0.42) and presence of any single respiratory symptom (OR=0.3; 95%CI: 0.1–0.8) were statistically significant.

The observed values for each RI of the granite workers were compared with the derived predicted values calculated for the individual subject for his/ her age, sex and height (Table 3). The observed mean values of FVC (2.5 L), $FEV_{1.0}$ (2.4 L/sec) and PEFR (339.5 L/min) were significantly lower than the respective predicted values (3.2 L, 2.7 L/sec and 519.4 L/min). When analysing males and females separately, the male granite workers had significantly lower observed values for all the three RI in comparison to the predicted, where as for females only PEFR was shown to have a significantly lower observed value.

The proportion of smokers among males in the study and control groups were 60.5% (26/43) and 48.8% (21/43) respectively and the difference was not statistically significant. The number smoked per day and the duration of smoking among the two groups also did not differ significantly (Table 1). On comparison of smokers and non-smokers among granite workers, the non smokers were found to be older (30.5 versus 29.2 years) and having a longer duration of service (26.3 versus 19.1years) than smokers. However, none of these differences were statistically significant.

The proportion with symptoms in smokers (42%; [11/26] and 62%; [13/21] respectively) and non-smokers (32%, [8/25] and 66%; [20/30] respectively) among granite workers and the control group did not differ significantly. The proportion with symptoms in smokers among granite workers (42% [11/26]) and the control group (62% [13/21]) also did not differ significantly (Table 4). However, among the non-smokers, the granite workers (32%; [8/25]) were observed to have a significantly lower (p=0.02) proportion with respiratory symptoms than that of the control group (67%; [20/30]).

On comparison of RI of smokers and non-smokers among granite workers, the smokers were found to have higher mean values for all three indices namely FVC (2.6 versus 2.3 L), $FEV_{1.0}$ (2.7 versus 2.5 L/sec) and PEFR (375.1 versus 353.5 L/min) although the differences were not statistically significant.

Table 5 shows the distribution of granite workers according to the type of ventilatory impairment (VI). Among all workers, 24 (47.1%) had a restrictive type of impairment. This included 75% (6/8) of females and 41.9% (18/43) of males. Only one (2%) had obstructive type of impairment and that was a male. None had both types of impairment.

Seven (14%) among the granite workers with either type of impairment (47%; n=24) were found to present with symptoms. Only one (12.5%) female presented with respiratory symptoms but she was free of either type of ventilatory impairment.

None had radiological evidence of silicosis nor tuberculosis.

Table 1 – Description of relevant variables among granite workers and the control group

Variable	Description	Statistical test & Probability
Mean Age Study (n=51) Control (n=51)	 31.5 (SE =1.7) years 36.0 (SE = 1.7) years	 T Test 0.07
Smokers Study males (n=43) Control males (n=43)	 26 (60.5%) 21 (48.8%)	 Chi square 0.42
Mean number smoked /day Study Control	 5 cigarettes or beedi or both (SE =0.7) 4 cigarettes or beedi or both (SE = 0.6)	 T Test 0.49
Mean Duration of Smoking Study Control	 9 (SE = 2.1) years 13 (SE = 1.7) years	 T Test 0.11
Duration of service Study (n=51)	Median =1year IQ range=0.4 -1.6 years Range= 0.2 – 20 years	Not applicable

Table 2 - Comparison of respiratory symptoms in the two groups

Respiratory Symptom	**Granite n = 51**	**Control n = 51**	**Odds Ratio (95% CI)**
Cough < 3months	4 (8%)	9 (18%)	0.4 (0.1- 1.6)
Cough ≥ 3 months	4 (8%)	1 (2%)	4.3 (0.4-104)
Phlegm < 3months	6 (12%)	10 (20%)	0.6 (0.2-1.8)
Phlegm ≥ 3 months	8 (16%)	3 (6%)	3.0 (0.7-15.0)
Chronic Bronchitis	7 (14%)	4 (8%)	2.2 (0.5-9.4)
Asthma	3 (6%)	2 (4%)	1.5 (0.2-13.8)
Dyspnoea	5 (10%)	23 (45%)	**0.1 (0.04-0.42)**
Other respiratory / heart illness	2 (4%)	5 (10%)	0.4 (0.1-2.4)
Total with any single respiratory symptom	19 (37%)	33 (65%)	0.3 (0.1-0.8)
Any single respiratory symptom with no other illness	17 (33%)	28 (55%)	**0.4 (0.2-0.91)**

Table 3 - Comparison of pulmonary function with predicted values of granite workers (n=51)

Respiratory Indicator	**Observed Mean (SE)**	**Predicted Mean (SE)**	**Probability***
FVC- L	2.5 (0.10)	3.2 (0.05)	<0.0001
$FEV_{1.0}$–L/sec	2.4 (0.10)	2.7 (0.05)	0.001
PEFR-L/min	339.5 (15.7)	519.4 (5.6)	<0.0001

* T Test – Unequal variance

Table 4 – Comparison of respiratory symptoms among smokers and non smokers in the two groups

Presence of symptoms	**Granite Workers (n=51)**		**Controls (n=51)**	
	Smokers	**Non Smokers**	**Smokers**	**Non Smokers**
	(n=26)	**(n=25)**	**(n=21)**	**(n=30)**
No Symptoms	15 (58%)	17 (68%)	8 (38%)	10 (33%)
Chronic bronchitis	3 (12%)*	4 (16%)**	3 (14%)*	1 (3%)**
Other respiratory Symptoms	8 (31%)*	4 (16%)**	10 (48%)*	19 (63%)**

Statistical analysis: presence of symptoms among smokers in the two groups:
Smokers in the two groups: "no symptoms" versus "with symptoms" (*pooled for the analysis); Chi Square value = 1.09; df=1; p = 0.3
Non smokers in the two groups: "no symptoms" versus "with symptoms" (**pooled for the analysis); Chi Square value = 5.2; df=1; p = 0.02

to the general population and as far as was feasible the respondents selected were ones who met the above criterion.

$FEV_{1.0}$ which is considered to be efficient in detecting large and medium sized airway function and PEFR which denotes large airway function (8) were observed to be significantly lower than the predicted values in the granite workers. Hence it may be deduced that granite workers were affected with both large and medium airway function despite the short median duration of exposure which was one year with a range of 0.2 to 20 years. The inability to assess $FEF_{25\%-75\%}$ in this study, which is a more sensitive indicator of small airways disease, is considered a limitation (8).

The short, median duration of work, may be suggestive of rapid turn over of workers. Individual susceptibility has a role to play in the development of respiratory illness and the workers who are able to withstand the adverse effects of silica dust will have the tendency to continue in the job. This may be further reinforced by working outdoors with limited exposure time. It is noted, that the maximum duration of 20 years was contributed by one single worker who was affected with chronic bronchitis and dyspnoea.

Forty seven percent (n=24) of all granite workers presented with restrictive lung disease. Forty two percent (n=18) of males and 75% (n=6) of females were affected with restrictive lung disease. Only one was affected with obstructive lung disease. Restrictive lung disease has been associated with production of collagen and fibroblast growth factors, resulting in fibrosis in the alveolar walls and to formation of silicotic nodules (7). However, in the present study it may be attributed purely to the former, in the absence of radiological evidence of silicotic nodules.

Even though 49% (24 [47%] restrictive and 1 [2%] obstructive) of granite workers showed evidence of either form of ventilatory impairment, only 28% (7/25) were observed to suffer from respiratory symptoms. This emphasises the need to intervene early before they become incapacitated with symptoms. Regular surveillance of the workers by carrying out lung function tests will help to identify these early cases, making application of early interventions (secondary prevention) possible. However, this should not at any cost, undervalue the importance of primary preventive measures such as reducing dust at the point of origin and the use of industrial masks.

The evidence available from other studies with regard to silicosis and VI are not consistent. Ng and Chan (10) showed that lung function impairment was directly attributable to fibrotic lung disease arising as a result of respirable silica. Longitudinal pulmonary function assessment carried out among Vermont granite workers between 1979 and 1987, had shown that VF loss is not accelerated by the dust levels, since its control conformed to Occupational Safety and Health Administration (OSHA) permissible exposure limits (11). However, a study reported in 2002 (12) in the United States indicates that there is still an associated decline in VF due to cumulative silica exposure even within the current allowable OSHA regulatory levels.

Silicosis has a long latent period. The short median duration of work in the granite industry which was one year, may not be sufficient enough to show any significant changes. In the study done on radiographic abnormalities among Vermont granite workers exposed to low levels of granite dust, only 3% showed abnormalities consistent with pneumoconiosis and of them only 0.7% showed clear evidence of uncomplicated silicosis (9). Undetected silicotic nodules in the lungs is postulated to give rise to airflow obstruction in granite workers even without radiological evidence of silicosis. This has been confirmed by computed tomography studies which are more sensitive in detecting confluent silicosis (7) than chest radiography. However, the applicability of the latter as a routine investigation in Sri Lanka is doubtful, owing to the prohibitive costs involved.

Exposure to silica dust is considered to increase the risk of tuberculosis even without the presence of silicosis. The absence of radiological evidence of tuberculosis which is a common condition in Sri Lanka, among the granite workers is therefore encouraging. However, long term follow up is required before being complacent about the findings in this study.

Evidence is available to suggest that smoking potentiates the effect of silica dust on lungs (7). When non-smokers show a decrease in residual lung capacity with restrictive impairment, smokers have been known to present with airflow obstruction with emphysema like functional changes (7). In the present study the smokers were observed to have better VF than the non-smokers although statistically not significant, it is contrary to the above findings.

With regard to the granite workers, the only possible explanation of the above findings is that the smokers were about one year younger and had a duration of service of seven years less than the non-smokers, and the amount smoked on average was five cigarettes/ beedi (local tobacco smoke) per day over an average duration of nine years. It is stated that smokers may initially have more robust lungs that can withstand the tobacco insult (13). This may have been further reinforced by the relatively younger age of the smokers combined with a lower duration of exposure to silica dust than the non-smokers. Based on the above findings it may also be postulated that the effect of silica on the respiratory system is far worse than the effect of smoking.

With regard to the symptoms, there was no significant difference observed in smokers and non smokers among granite workers and in smokers among granite workers and the control group. The statistically significant difference observed with regard to the symptoms were due to the difference in the proportions with symptoms among the non smokers in the two groups, where the non-smokers among the control group (66% versus 32%) were affected more. Thus the findings of this study reflect smoking as having a non-contributory role in the development of respiratory ill health in terms of both RI and respiratory symptoms in the study groups.

This is a cross-sectional analytical study associated with its characteristic limitation of not being able to assess temporal relationships. Inability to account for changes in the exposure levels is another deficiency in this design. A comparison of ventilatory function among controls may have improved the validity of the study which was made impossible due to logistical constraints. The spirometer was placed in the Medical Faculty and the research participants had to come there for the tests. Since the controls were scattered all over the community, it was not possible to arrange transport for them to come to the Medical Faculty for spirometry. The spirometer was placed in the Medical Faculty and the research participants had to come there for the tests. Since the controls were scattered all over the community, it was not possible to arrange transport for them to come to the Medical Faculty for spirometry. The situation with regard to granite workers was different as they were clustered in the few selected granite quarries.

The study was confined to the Kandy Municpality limits because of logistic constraints encountered in transporting workers from the work site to the Medical Faculty where the lung functions were carried out. The granite industry is a small scale industry with an average of less than five workers at a given site. Even though transport was provided it is unlikely that all from a given work site would attend on the same day. Thus the total number of granite workers recruited was 51 as we had to limit the study to in and around the Kandy Municipality limits. A higher sample size would have enabled adequate power to detect significant differences had there been any.

This is the first study to report lung function among workers in quarries installed with crushers in Sri Lanka. Even though there is no evidence to suggest the presence of silicosis which is a progressive and a disabling disease, evidence of VI calls for the adoption of preventive measures. The ideal should be installation of exhaust ventilation to capture the dust generated at the crusher. Provision of industrial masks which prevent inhalation of respirable silica particles is the next option along with limiting exposure time. The need for follow up studies is also emphasised.

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Table 5 – Type of ventilatory impairment among granite workers

Type	Total n=51	Males n=43	Females n=8	FVC % of predicted	$FEV_{1.0}$/FVC %
Restrictive (R)	24 (47.1%)	18 (41.9%)	6 (75.0%)	<75	≥70
Obstructive (O)	1 (2.0%)	1 (2.3%)	0 (0.0%)	≥75	<70
R + O	0 (0.0%)	0 (0.0%)	0 (0.0%)	<75	<70
Normal	26 (51.0%)	24 (55.8%)	2 (25.0%)	≥75	≥70

Discussion

The study findings indicate that the respiratory function of the granite workers were significantly impaired with regard to all the indices studied in comparison to the predicted normal values. A higher proportion of granite workers had cough and phlegm, equal to or more than three months duration and chronic bronchitis, which were not statistically significant. They were free of radiological evidence of silicosis and tuberculosis.

The fact that the granite workers had a higher prevalence of chronic cough and phlegm (defined as lasting over equal or more than three months duration) and chronic bronchitis may be a reflection of the effect of exposure to silica dust. Lack of statistical significance may be explained by small sample included in the analysis.

There is epidemiological evidence to suggest that exposure to silica dust can give rise to chronic obstructive pulmonary disease (COPD) independent of silicosis (6). COPD (defined as presence of airflow obstruction due to chronic bronchitis or emphysema) arise due to chronic inflammation and remodelling of small airways and destruction of lung parenchyma in response to inhalant oxidants generated by smoking and other environmental exposures such as silica dust. There are two potential mechanisms through which silica is postulated to cause pathogenecity in the lungs: 1) by initiating a toxic and inflammatory processes in the conducting and peripheral airways and alveolar tissue which increases the production of oxidants, cytokines, chemokines and elastase leading to airways inflammation and emphysema or 2) by causing epithelial cell injury which facilitates penetration of silica particles of the small airways causing localised fibrosis (7).

The control group was on average 4.5 years older than the granite workers the difference of which was not statistically significant. It is unlikely that this small age difference could account for the observed higher proportions with cough and phlegm of less than 3 months duration, dyspnoea and presence of any single respiratory symptom among the controls. The episodes of cough and phlegm experienced by the latter group often did not exceed one to two weeks, suggestive of common acute respiratory illnesses. In comparison a higher proportion of granite workers were suffering from chronic (with a duration of equal or more than three months) respiratory episodes which may be attributed to their occupational exposures. Presence of dyspnoea among a significantly higher proportion of controls is difficult to explain, considering the lower proportion of them having chronic cough and phlegm (Table 2 - a total of three as one had both cough and phlegm). Of the 23 controls who presented with dyspnoea, eight (35%) were unemployed, and among them two were students of less than 25 years of age with no other concurrent illness. There were only four (17.4%) with other illness which could possibly account for the presence of it. Dyspnoea has a subjective element and the above finding may be a reflection of it.

The proportion of respondents suffering with other chest ailments was also higher among the control group which reflects the fact that controls were less healthier than the granite workers. This is may be attributed to the phenomenon of "healthy worker effect" given the fact that controls were selected from the general population. This is a phenomenon where the general population is considered to be less healthy than those working. The only way to overcome this is by selecting a control group from another industry. However, it is rather a difficult task, as selection of the control should meet the condition of absence of exposure to dust, fumes and gases. Hence the need to restrict the control group .