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Effect of exposure to cement dust on Fractional Exhaled Nitric Oxide (FeNO) in non-smoking cement mill workers

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Abstract. – OBJECTIVES: This cross-sectional study aimed to determine the effects of exposure to cement dust on Fractional Exhaled Nitric Oxide (FeNO) in non-smoking cement mill workers.

SUBJECTS AND METHODS: We recruited 121 apparently healthy male volunteers, 90 of them were non-smoking cement mill workers and 31 non-smoking un-exposed subjects served as control. The mean age of cement mill workers was 36.62 ± 1.03 years and 36.65 ± 2.28 years of control subjects. Based on the duration of exposure, cement mill workers were divided into four groups, less than 5, 5-10, 10-15 and more than 15 years. All subjects were individually matched for age, ethnicity and socioeconomic status. Fractional Exhaled Nitric Oxide test was performed by using Niox Mino.

RESULTS: Significant increased level of Fractional Exhaled Nitric Oxide was observed in cement mill workers (31.71 ± 2.963 ppb) compared to their non-exposed counterparts (25.39 ± 2.46 ppb). The significance difference was further increased with long-term working exposure in cement industry.

CONCLUSIONS: Fractional Exhaled Nitric Oxide is significantly increased in cement mill workers and associated with duration of exposure to cement dust. The findings also show that cement mill workers have higher pulmonary inflammation.

Key Words:
Cement dust, Fractional exhaled nitric oxide, FeNO, Lung inflammation.

Introduction

Globally large number of industrial workers or people living in the vicinity of industrial areas is facing increasing risks of respiratory problems. Air pollution is a very important occupational problem at various industries. The production of dust or fumes in industrial sectors causes air pollution which is associated with a wide range of adverse respiratory events[1,2]. The health risk posed by different concentration of inhaled dust particles is influenced by the duration of exposure and the biological responses exerted by the particles[3,4]. Cement industry workers are exposed to dust at various manufacturing and production processes[5]. Portland cement dust is a mixture of calcium oxide, silicon oxide, aluminum trioxide, ferric oxide, magnesium oxide, sand and other impurities[6]. The cement dust particles are within the respirable extent. They are toxic and irritant to the respiratory air passage and lungs and cause respiratory illness. Exposure to cement dust can cause numerous health hazards including the onset of acute or chronic respiratory illness, chronic obstructive pulmonary disease, respiratory function deficits[7], pulmonary inflammation and asthma[8].

Measurement of Fractional Nitric Oxide (NO) in exhaled breath (FeNO) is a simple, safe, reliable and non-invasive tool in assessing the severity of pulmonary inflammation and asthma[9]. NO is produced by the human lung, present in the exhaled breath and play major role in biology and pathophysiology of lung diseases including asthma[10]. Patients with asthma have high levels of NO in their exhaled breath[10]. FeNO becomes more popular among internal medicine in general and respiratory, occupational and environmental health physicians in particular as a new tool to assess the respiratory ailments. Literature is acutely lacking in FeNO and cement dust. The present study has also attempted to minimize mystifying interpretational factors by using same age, gender, ethnicity and socioeconomic status between the groups, excluding smokers and workers with previous industrial exposure other than cement industries. This study aimed to determine the effects of exposure to cement dust on FeNO and also provide information to cement mill workers about the significance of FeNO and hazards of cement dust.

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Subjects and Methods

Subjects

This cross sectional study was conducted in the Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia during the period Jan 2013-Dec 2013. In this study, 121 cement mill workers, working at the same cement plant were selected. A detailed interview of the subjects was conducted followed by history taking and clinical examination to determine whether to include him in the study or not. All the participants were questioned with regards to cigarette smoking, shisha smoking and other tobacco products. After the interviews, clinical history taking and examination, 90 apparently healthy, volunteer, male cement mill workers with mean age 36.62 ±1.03 years were selected. They were further divided into four groups based on the duration of exposure less than 5, 5-10, 10-15 and greater than 15 years. The participants worked for at least 8-10 hours a day for six days per week. These 90 cement mill workers were matched with another group called un-exposed (control) group. The control group was selected in a similar way. Initially, 100 subjects were interviewed, clinical history and examination were conducted, finally 31 age, ethnicity and socioeconomic status matched volunteer, healthy men with mean age 36.65 ± 2.28 years (mean±SEM) were selected. The control group primarily consisted of university staff including receptionist, secretaries, porters and research assistants. All subjects were individually matched for age, gender, ethnicity and socioeconomic status. The Institutional Review Committee, College of Medicine, King Saud University approved the study.

Exclusion Criteria

Subjects with known cases of gross anemia, diabetes mellitus, chronic obstructive pulmonary diseases, malignancy, drug addicts and cigarette or shisha smokers were excluded. The subjects who were taking vigorous exercise regularly or working in any industry which generate dust or fumes other than cement industry were excluded from the study.

Methods: Fractional Exhaled Nitric Oxide (FeNO)

Fractional Exhaled Nitric Oxide (FeNO) concentration was measured by using Niox Mino, Aerocrine, Solna, Sweden. The FeNO device was pre-calibrated for a predetermined life span (300 measurements) from the manufacturer; hence, the device did not require re-calibrations in the field. Tests were carried out at a fixed time of the day to minimize the diurnal variation of FeNO concentration[11]. The defined techniques in executing FeNO test for the present study were based on the operation manual of the instrument with special reference to the official statement of the American Thoracic Society/ERS Standardization procedure for FENO measurements[9]. After taking a detailed history and anthropometric data, the subjects were informed about the whole maneuver. All measurements of cement mill workers were conducted in the dispensary of cement factory, and for control group all measurements were performed in the Physiology Lab of College of Medicine, KSU. The tests were performed with the subject in the standing position along with using a nose clip. The results were recorded appeared on the screen of Niox Mino.

Statistical Analysis

The data were entered into the computer and analyzed by using the Statistical Package for Social Sciences (SPSS) version 20.0 programs for windows (SPSS Inc., Chicago, IL, USA). Unpaired Student's *t*-test was applied to test the difference of the means between the two quantitative variables. The level of significance was assumed at $p < 0.05$.

Results

Table I presents the mean values of FeNO and age for the cement mill workers and the control group. The statistical comparisons of the matching variables including age, ethnicity and socioeconomic status were similar for both groups. The mean age of cement mill workers was 36.62 ±1.03 (mean ± SEM) range 22-64 years and control group was 36.65 ± 2.28 (mean ± SEM) range 21-60 years. The mean FeNO of cement mill workers was 31.71 ± 2.96 ppb compared to their control group 25.39 ± 2.46 ppb. The FENO was significantly increased in cement mill workers ($p = 0.001$) compared to their control group.

Table II summarizes the comparison of the FeNO between cement mill workers with duration of exposure to cement industry less than 5, 5-10, 10-15 and more than 15 years and the control group. There was a no significant change for FeNO in cement mill workers who have working

Table I. Comparison of Fractional Exhaled Nitric Oxide (FeNO) between cement mill workers and control.

Parameters	Cement mill workers (n=90) mean ± SEM	Control (n=31) mean ± SEM	*p*-value
Age (years)	36.62 ± 1.03	36.65 ± 2.28	$p = 0.64$ [NS]
FeNO (ppb)	31.71 ± 2.96	25.39 ± 2.46	0.0001

Values are presented as mean ± SEM; NS = non-significant.

Table II. Fractional Exhaled Nitric Oxide data for cement mill workers with duration of exposure less than 5, 5-10, 10-15 and more than 15 years compared to their matched controls.

Parameters	Cement mill workers	Control	*p*-value
Duration of exposure (years) Mean ± SEM (Range)	FeNO (ppb) Mean ± SEM	FeNO (ppb) Mean ± SEM	
less than 5 years 1.52 ± 0.14 (1-4)	(n = 47) 25.23 ± 3.98	(n = 31) 25.39 ± 2.46	0.52 NS
5-10 years 6.93 ± 0.51 (5-10)	(n= 14) 31.14 ± 6.07	(n=31) 25.39 ± 2.46	0.14 NS
10-15 years 12.09 ± 0.37 (10-15)	(n = 11) 34.80±5.19	(n=31) 25.39 ± 2.46	0.01
More than 15 years 21.78 ± 1.21 (16-34)	(n= 18) 63.38 ± 20.33	(n=31) 25.39 ± 2.46	0.001

Values are presented as Mean ± SEM; NS = non-significant.

exposure of less than 5 years 25.23 ± 3.98 compared to their control group 25.39 ± 2.46 [p = 0.52] and 5-10 years of exposure to cement mill 31.14 ± 6.07 compared to control group 25.39± 2.46 [p = 0.14]. The mean duration of exposure among the subjects in the first age group (> 5 years) was 1.52 ± 0.14 years (mean ± SEM), range 1-4 years; and in the second age group (5-10 years) was 6.93 ± 0.51 range 5-10 years.

Cement mill workers exposed for 10-15 years showed a significant increase in FeNO (34.80 ± 5.19) compared with their controls (25.39 ± 2.46) [p = 0.01]. The mean duration of exposure in these cement mill workers was 12.09 ± 0.37 years (mean ± SEM), range 10-15 years. Table II also summarizes the data of cement mill workers exposed for more than 15 years which showed a significant increase in FeNO (63.38 ± 20.33) compared with their controls (25.39 ± 2.46) (p = 0.001). The mean duration of exposure in this group of workers was 21.78 ± 1.21 years (mean ± SEM), range 16-34 years.

The results also show that FeNO was increased among cement mill workers with age group more than 40 (Figures 1, 2). Moreover, based on the different departments (profession) of cement mill workers, FeNo was higher in drivers, labors, mechanics, crane operators and supervisors (Figure 3) compared to lab technicians and security people as drivers, labors, mechanics, crane operators and supervisors are in direct contact to cement dust.

Pearson correlation coefficient was measured between duration of exposure and FeNO among cement mill workers (Figure 4). There was a sig-

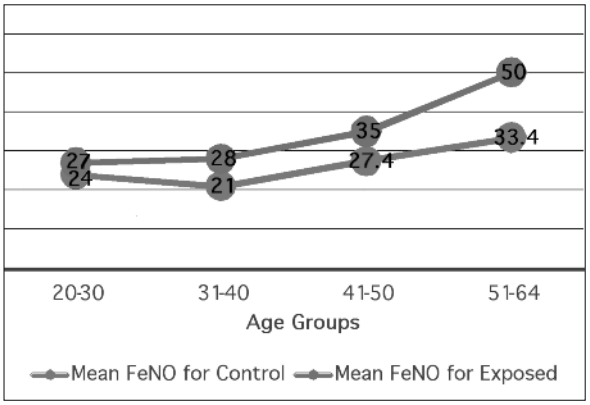

Figure 1. Comparison of Fractional Exhaled Nitric Oxide between control and cement mill workers based on their age groups.

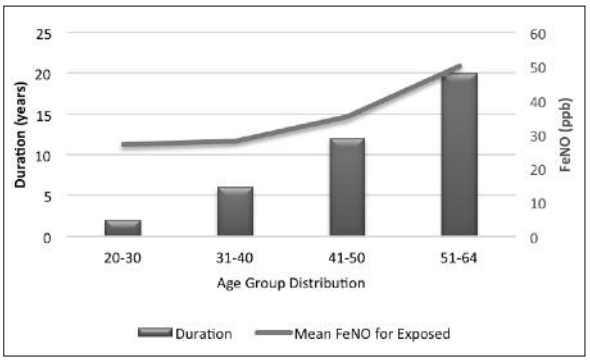

Figure 2. Fractional Exhaled Nitric Oxide among cement mill workers based on their duration of exposure to cement dust.

nificant association between duration of exposure and FeNO (r = 0.390; p = 0.0001) among cement mill workers (Figure 4).

Discussion

Occupational exposure to cement dust and its effects on respiratory system are leading health problems. Literature is available on lung function and cement dust[2,4,7]. However, the applications of a new tool, Fractional Exhaled Nitric Oxide (FeNO) and cement dust is acutely lacking. The present study found that FeNO is significantly increased in cement mill workers compared to their non-exposed counterparts. The significance difference was further increased in cement mill workers who had been working in the cement industry for more than 10 years (Table II, Figure 4). It shows that duration of exposure is a major risk factor in cement mill workers.

FeNO is a popular, reliable, non-invasive and an established marker of air way inflammation[12] and useful in the assessment of asthma status[13]. Flamant-Hulin et al[14] reported that FeNO is a potential marker of airway inflammation due to air pollution and its levels are significantly elevated in both asthmatic and non-asthmatic subjects exposed to high concentrations of environmental pollution.

High FeNO levels can suggest a subclinical inflammation of the airways, even in the absence of symptoms and impairment of lung function[15]. Since airway inflammation is a hallmark of asthma, FeNO measurement is potentially useful to evaluate the impact of air pollution on the inflammatory state of airways.

La Grutta et al[16] reported that, occupational and environmental factors and indoor and outdoor air pollution play an important role in triggering acute exacerbations of respiratory symptoms. They reported the effects of outdoor and indoor pollutants on FeNO in children. Their findings were not consistent, but urban and industrial pollution mainly particles nitrogen dioxide (NO_2), sulfur dioxide (SO_2) as well as formaldehyde have been shown to increase the FeNO levels.

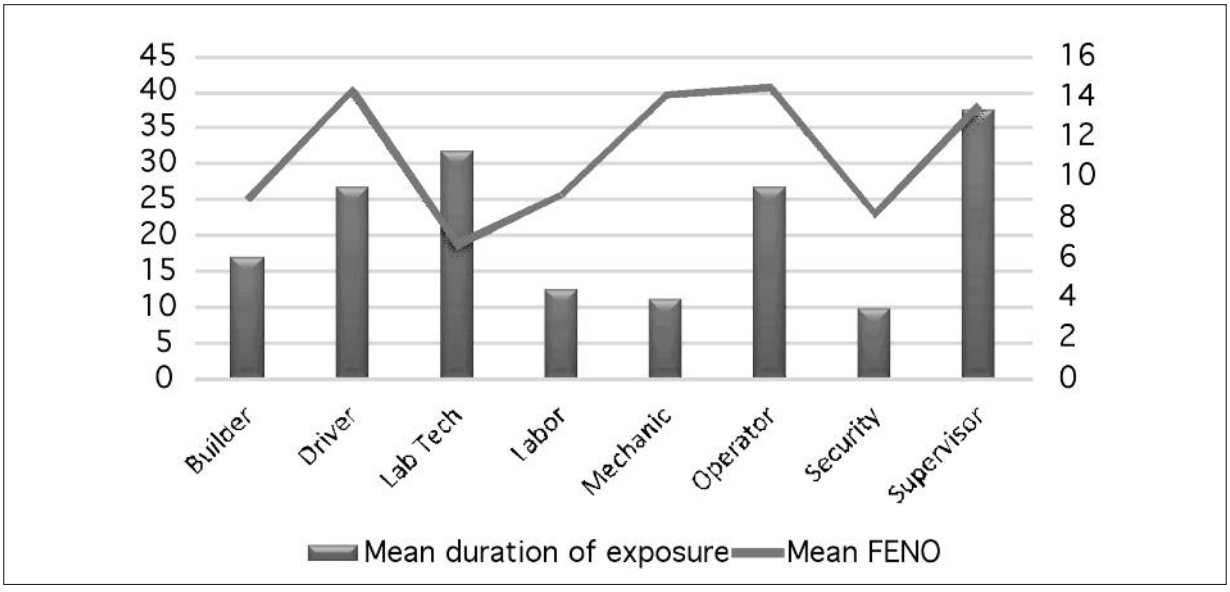

Figure 3. Fractional Exhaled Nitric Oxide of cement mill workers based on their profession and duration of exposure in cement industry.

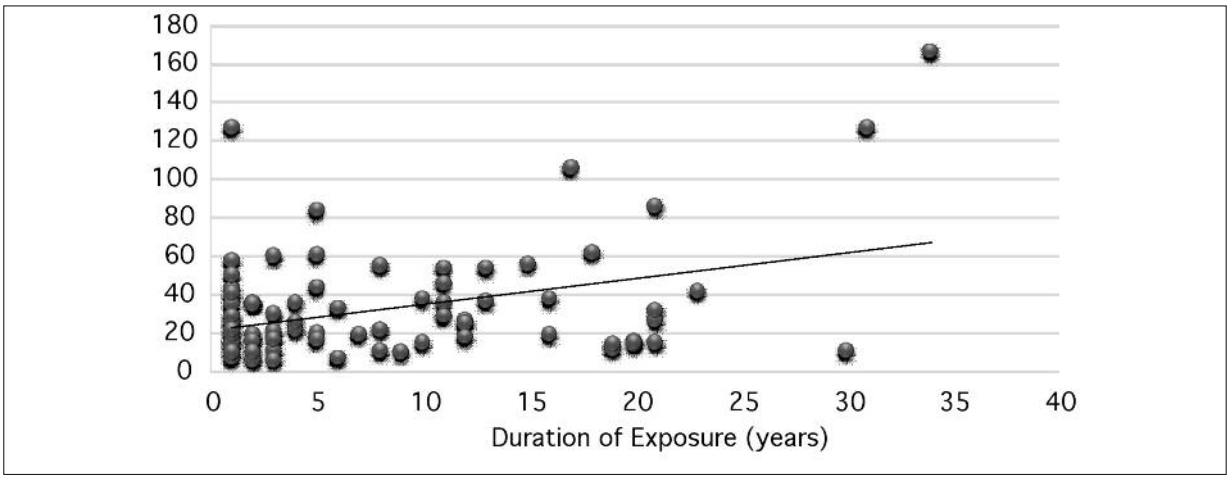

Figure 4. Pearson correlation coefficient between duration of exposure and Fractional Exhaled Nitric Oxide among cement mill workers.

Van der Walt et al[17] conducted a cross-sectional study of 150 workers who were exposed to garlic and chili pepper. They found that exposure to inhalable spice dust containing garlic and chili pepper increase the risk of allergic respiratory disease and asthma and among workers and FeNO was found to be elevated to more than 50 ppb in 4% and 8% of workers respectively.

Sandrini et al[18] conducted a cross section study in 56 subjects with asbestos-related disorders and in 35 normal subjects. They found that FeNO was elevated in subjects with asbestosis consistent with lung inflammation compared with normal controls.

Adamkiewicz et al[19] measured the association between air pollution levels and FeNO. They found that an increase in the 24 hour average PM (2.5) concentration was associated with an increase in FeNO levels, and reported that ambient pollution may lead to airway inflammation as measured by FeNO.

Ulvestad et al[20] reported that exposure to gases and dust induces airway inflammation. It was hypothesized that heavy construction workers who had been exposed to dust and gases in underground construction work for 1 year would have early signs of upper and lower airway inflammation as compared to outdoor workers. A study group comprising 29 non-smoking underground concrete workers and a reference group of 26 outdoor concrete workers were examined. The underground workers had higher exposure to total and respirable dust alpha-quartz and nitrogen dioxide. FeNO was higher in the underground workers than in the reference group. It was also hypothesized that exposure to underground construction increased the levels of FeNO indicating signs of airway inflammation.

Lund et al[21] reported higher FeNO among 99 non-smoking Aluminium smelters than among 40 control subjects, suggestive of inflammation, Similarly, Sjaheim et al[22] conducted a study on Potroom workers who were exposed to a complex mixture of particulates and gases. The respirable particles of the pot fume emissions are mainly composed of aluminium oxide, carbon dust, and cryolite to which gases such as hydrogen fluoride and sulphur dioxide are absorbed. In non-smoking subjects, the concentrations of exhaled FeNO were significantly higher in workers than non-exposed controls.

In agreement to our findings, Sauni et al[23] examined 94 silica-exposed workers and 35 healthy volunteers and measured the NO concentration. The authors reported that exposure to silica dust causes inflammatory responses, primarily in the lungs and alveolar inflammation demonstrated by increased alveolar concentration of NO. They found that silica exposure was associated with significantly higher levels of FeNO indicating inflammatory effects of silica in the peripheral lung.

Conversely, Carlsten et al[24] conducted a cross-sectional study of 11 cement mason apprentices and 21 electrician (control) apprentices. FeNO was measured and there were no significant differences in FeNO concentrations among cement mason apprentices compared with electrician (control) apprentices. The most probable reason for this contradiction was the selection of electricians in a control group. As it is well established

fact that electricians are at higher risk to develop occupational health risk including asthma[25]. This could be the reason for the non-significant difference in the FeNO of cement mason.

Conclusions

A significant increase in the FeNO was found in cement mill workers compared to their non-exposed counterparts. The significance difference was further increased among cement mill workers who had been working in the cement industry for more than 10 years compared to their matched unexposed group, which indicates that duration of exposure is an independent and major risk factor to the cement mill workers. The findings also show that cement mill workers have higher pulmonary inflammation. The findings are of reputation in that they highpoint the need to reduce long term exposure and show the magnitude of the effect in a population. It is advisable that health risk should be reduced by the collaboration between health officials, cement mill workers and the management to adopt technical preventive measures to minimize the risk. It is also suggested that workers must undergo pre-employment and periodic medical examinations including FeNO test. It is also proposed that long term exposure to cement industries should be evaded and workers must be given official days off at least two times in a week and two months in a year. It is also recommended that the industry management should arrange health safety and education sessions biannually for the workers to provide awareness.

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

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