Cross-Shift Study of Acute Respiratory Effects in Cement Production Workers

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Abstract- Cement dust exposure is associated with increased respiratory impairment. As the major occupational hazard in the cement production industry is cement particles, our aim was to more thoroughly examine the acute effects of occupational exposure to cement dust on the respiratory system. A cross-shift study was conducted in a cement factory in Iran. 100 high exposed workers from production and packing sections and 100 low exposed from office workers were included. Environmental total dust was measured in each section. Assessment of lung function was done by pre and post shift spirometry. At the end of the day shift, acute respiratory symptoms were recorded. The means of total dust among high and low exposed workers were 16.55 mg/m3 and 0.9 mg/m3, respectively. The most common acute respiratory symptoms in high exposed workers were stuffy nose (52 %) and shortness of breath (49 %). A statistically significant post shift reduction in PEF, FEV1, FEF 25-75, FVC and FEV1/ FVC was demonstrated in high exposed group. Multivariate linear regression showed a significant relationship between the percentage of the cross-shift decrease in spirometric indices and exposure to cement dust. We detected significant relationship between exposure to cement dust and acute respiratory symptoms and pulmonary function indices. Effective dust-control measures and preparing a suitable strategy for respiratory protection are highly recommended.

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Introduction

Over the recent decades the pace of industrialization and demand for cement has increased significantly, therefore, a large number of people are working daily in cement Industry. Cement plant produces cement through three processes: Raw material process, Clinker burning process, and Finish grinding process (1). These processes is done in the different part of cement plant and Raw material and clinker burning process are classified into wet, semi wet & dry process depend on the concentration of raw material entered the oven (2). Cement production is a dusty operation with risk of exposure to cement particles during most stages of manufacturing process (3). The Portland cement is composed of calcium oxide, aluminum trioxide, silicon dioxide, ferric oxide, dicalcium silicate (2cao.sio2), magnesium oxide, selenium, thallium, and low concentration of hexavalent chromium (4-6). Workers in cement factories are exposed to different health hazards during cement production and handling including cement dust , high temperature, and noise(5); however, the major occupational hazard in the cement production industry is cement particles which is emitted to the environment at most stages of production process with higher concentration in the crane, packing and crusher sections (1, 7-9).

Inhalation of cement dust irritates the mucous membrane of the respiratory system (10, 11). Fell AK *et al* found that the mean percentage of airway neutrophils and levels of interleukin-1β in induced sputum samples was significantly higher in the exposed period in comparison with unexposed period (4). This appears to confirm the hypothesis that cement dust stimulates inflammatory mechanism in the airways of workers. In another study Aminian *et al.* also observed significant higher mean concentrations of IgA in cases with exposure to silica in comparison with the control group (12). Workers in cement industry are at risk of developing occupational disease including respiratory disease (*e.g.* asthma, chronic bronchitis, silicosis, *etc.*) skin disorder (*e.g.* allergic dermatitis), Gastrointestinal

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(GI) disorders, and hearing and visual disorders (5, 13-16).

There is contradicting evidence in the literature regarding the associations between exposure to cement dust and respiratory symptoms or functional impairment (10, 11, 14, 17-19).

Several previous studies have confirmed the association between exposure to Portland cement dust at cement manufacturing plants and chronic effects on respiratory symptoms and lung function (13, 14, 20-23); however, further studies are required to elucidate the acute respiratory effects of exposure to cement dust.

A more recent study demonstrated across shift reduction in FEV1, FEF 25-75, DLCO and fractional exhaled nitric oxide (FeNo) levels; an increase in leucocytes, fibrinogen and TNF-α levels, and a decrease in the levels of IL10 (24) . Two studies have reported the high prevalence of acute respiratory symptoms and more pronounced cross-shift decrease in PEF among high exposed workers comparing to low exposed (7, 10).

In recent decades, millions of people are working in the cement industry without being appropriately trained, and without utilizing high quality facemasks and respiratory protective equipments, especially in developing countries. The main purpose of this study was to examine the acute effects of exposure to cement dust on respiratory symptoms and function with the purpose of providing evidence for the health issues.

Materials and Methods

This cross –shift study was conducted at a Portland cement factory in Iran between May and July 2011 .This factory was selected because it is one of the largest cement factories in Iran .The factory was established in 1969, started production activity in 1979, currently produces about 2 million tons of cement per year and has about 800 employed workers.

200 workers, who have been working for one year or more, had been selected, 100 workers from high exposed area and 100 from low exposed area. The exposed group comprised of workers from different sections of the production department including packing, crusher and mechanics and the low exposed group comprised Office workers. The study groups were selected from those with no past medical history of respiratory disease, no current respiratory illness, and no reported history of working in an environment exposed to welding fumes, spray paints, or chemicals.

Exposure assessment

Resistance Exposure was measured by sampling total dust on polyvinyl chloride filters with a pore size of 5 -µm placed in 37-mm filter cassette. Each pump was calibrated by a digital automatic calibrator before and after sampling. Dust concentration was measured in each section on four different days one week prior to the study from 5 different parts. The mean sampling time was 420 minutes. Dust concentration expressed in mg/m3 was calculated from the changes in the dried filter before and after sampling. The mean of total dust in each section was chosen for analysis. Also, Personal total dust was measured in the breathing zone of the 20 workers from high exposed group and for 20 of the low exposed group. Total dust was collected on pre weighed cellulose acetate filters with a pore size of 0.8 µm placed in a closed face 37-mm filter cassette(Millipore) connected to an SKC sidekick pump with a flow of 2.0 l/min. sampling was performed during the day shift; the sampling time varied from 365 to 470 minutes. Total dust was measured quantitatively by gravimetric analysis using a Mettler microbalance. We compared the results from the occupational exposure monitoring with the current American Conference of Governmental Industrial Hygienists *(ACGIH)* TLV for total dust exposure of 10 mg/m^3(25).

Assessment of respiratory health effects

A single investigator conducted the interviews to complete the questionnaire for each subject. Before the study, this questionnaire was translated from English to Persian and back translated to English by two people. This questionnaire (26) included socio-demographic data, smoking habits, use of personal protection equipment and respiratory history. At the ends of the eight-hour day shift, the acute respiratory symptoms experience that day (cough, shortness of breath, stuffy nose, runny nose and sneezing) were scored and recorded on a five-point Likert scale as never [1], mild [2], moderate [3], severe [4] or very severe [5] using a modified respiratory symptom score questionnaire (27). In the analysis, we recorded no for never and yes for other scores. Lung function tests were performed in accordance with *ATS/ERS* guidelines (28) using the portable spirometer (Spiro lab3) within 30 minutes before and after the shift for each worker. Before the test height and weight of workers were measured. The tests were performed with the subject seated, and three acceptable maneuvers were performed and the best result, according to *ATS/ERS* criteria was entered in the analysis. The percentage acute cross-shift change in spirometric indices was calculated as *[(Post shift index-pre shift index) / pre shift index] *100*

The study was approved by the ethical committee of occupational medicine department. Study design was explained to all workers participating in the study and written consent was obtained from all of them.

Analysis

The data were analyzed using SPSS and P<0.05 was defined as statistical significance. Demographic data between groups were compared using Independent t test and chi-square (or the fisher exact test) and Comparisons of each acute respiratory symptom between the groups were performed using fisher exact test. Independent t-test was used to compare cross-shift changes in spirometric indices. Multiple linear regression analysis was used to evaluate the relation of ΔPEF, ΔFEV1, ΔFVC, Δ FEF 25-75 to exposure and pack year while adjusting for age and employment duration and BMI.

Result

For the high exposed worker, the mean total dust in sections were: 20.2 mg/m3 (crusher), 18.4 mg/m3 (packing), 15.1 mg/m3 (mechanics) that all exceeded the TLV of 10 mg/m3.The mean concentration of total dust for low-exposed workers was 0.9 mg/m3, and none of the samples exceeded the TLV. For both groups the geometric means *(GM)* of personal total dust were similar to the mean of environmental total dust samplings.

The mean age was 33.65 years (ranging from 21-56). The high exposed workers were significantly younger, had been employed for fewer years and had lower education level than the low exposed worker (Table 1). However, Height, weight, BMI and smoking habits between two groups did not differ significantly (Table 1).

Table 1. Demographic data on 200 male cement factory workers

parameters	High Exposed (n=100) Mean±SD	low exposed (n=100) Mean±SD	p
Age (years)	31.65 ± 6.95	35.65 ± 7.88	***†
Height (cm)	174.9± 6.58	175.2± 6.38	NS †
Weight (kg)	76.37 ± 9.72	78.01 ± 11.73	NS †
BMI (kg/m2)	24.92± 2.97	25.33± 3.38	NS †
Employment(years)	6.77 ± 5.76	9.87 ± 7.06	** †
Education level			
Primary, n (%)	61 (61)	21 (21)	***‡
Post Primary, n (%)	39 (39)	79 (79)	***‡
Smoking habits			
Current smokers, n (%)	20 (20)	16 (16)	NS ‡
Nonsmokers, n (%)	78(78)	80 (80)	NS ‡
Ex-smokers, n (%)	2(2)	4 (4)	NS ‡
Pack year	3.21± (3.13)	5 ± 4.48	NS †

SD (Standard deviation). † Independent t test. ‡Chi- square test. NS (not significant)
Nonsmoker (never smoked), ex-smoker (stopped smoking more than 1 year before the survey), current smoker (smoking daily for more than 1 year), ** P<0.01; ***P<0.001

The mean duration work was 8.32 years with the range of 1-26 y for the high exposed workers and 1-28 y for the low exposed workers and 61% of the high exposed workers and 21% of low exposed workers had primary education. A total of 40 (40%) of the high exposed workers reported using disposable masks *(type P2)* during work shift.

The high exposed workers had significantly higher prevalence for acute respiratory symptoms except for Runny nose than the low exposed workers (Table 2).

Table 2. Acute respiratory symptoms among 200 male cement factory workers categorized into high exposed and low exposed groups

Acute respiratory Symptoms	High exposed (n=100)		low exposed(n=100)		P value
	N	%	N	%	
Stuffy nose	52	52	6	6	*** †
Shortness of breath	49	49	2	2	*** ‡
Sneezing	26	26	1	1	*** ‡
Cough	11	11	0	0	** ‡
Runny nose	9	9	3	3	NS †

† Chi-square test. ‡ Fisher's exact test. NS (not significant). ** P<0.01; ***P<0.001

The most common acute respiratory symptoms for the high exposed workers were stuffy nose (52%). Only 12 workers in the low exposed group reported acute respiratory symptoms with the highest prevalence for stuffy nose (6%).Although the high exposed group had higher per shift spirometric indices than the low exposed group (table 3) and the two groups did not differ significantly in post shift indices, the percentage of cross shift change in indices differed significantly between two groups. We detected the highest decrease in indices in PEF 460 ml/s (5%) and FEV1 100ml (2.5%), respectively. Selected lung function indices are presented in table 3.

Table 3. Cross-shift changes in spirometric indices

Spirometry indices	High exposed group(n=100) Mean(SD)	Low exposed group(n=100) Mean(SD)	P value
Pre shift PEF (L/S)	9.51(1.50)	9.34(1.44)	NS†
Post shift PEF (L/S)	9.05(1.42)	9.54(1.52)	**†
ΔPEF %	-4.96(3.49)	2.13(2.43)	***†
Pre shift FEV1(L)	3.78(0.62)	3.59(0.55)	NS†
Post shift FEV1(L)	3.68(0.60)	3.62(0.57)	NS†
ΔFEV1%	-2.52(1.45)	0.94(1.56)	***†
Pre shift FVC(L)	4.73(0.69)	4.52(0.62)	NS†
Post shift FVC(L)	4.66(0.68)	4.57(0.63)	NS†
ΔFVC%	-1.64(1.36)	1.05(1.19)	***†
Pre shift FEF 25-75(L/S)	3.53(0.89)	3.42(0.90)	NS†
Post shift FEF25-75 (L/S)	3.46(0.89)	3.46(0.92)	NS†
ΔFEF 25-75%	-2.23(2.02)	0.94(3.15)	***†
Pre shift FEV1/ FVC (%)	79.79(6.18)	79.34(5.1)	NS†
Post shift FEV1/ FVC (%)	79.09(6.16)	79.26(5.24)	NS†
ΔFEV1/ FVC%	-0.87(1.02)	-0.11(1.23)	***†

indices=[(post shift index – pre shift index)/pre shift index] *100Δ

† Multiple linear regression adjusted for age, employment duration and education level. NS (not significant),*P < 0.05; ** P<0.01; ***P<0.001

Table4. Multiple linear regression models for percentage cross-shift changes in spirometric indices among 200 male cement workers

	Covariate	B	SE	β	P	CI 95%
Δ PEF % **R^2=0.61**	Constant	1.79	2.144		NS	-2.437,6.018
	Age	-0.038	0.049	-0.068	NS	-0.134,0.058
	BMI	0.062	0.066	0.042	NS	-0.069,0.193
	DUR. work	0.043	0.057	0.061	NS	-0.069,0.155
	Pack year	-0.297	0.089	-0.155	**	-0.472,-0.122
	Low vs. high	-7.175	0.43	-0.773	***	-8.024,-6.326
ΔFVC% **R^2=0.55**	Constant	0.548	0.925		NS	-1.276,2.373
	Age	0.013	0.021	0.054	NS	-0.028,0.055
	BMI	0.012	0.029	0.021	NS	-0.044,0.069
	DUR. work	-0.018	0.025	-0.063	NS	-0.066,0.031
	Pack year	-0.104	0.038	-0.136	**	-0.18,-0.029
	Low vs. high	-2.711	0.186	-0.732	***	-3.077,-2.344
Δ FEV_1% **R^2=0.62**	Constant	-0.736	1.051		NS	-2.808,1.336
	Age	0.019	0.024	0.063	NS	-0.028,0.066
	BMI	0.06	0.033	0.083	NS	-0.004,0.124
	DUR. work	-0.034	0.028	-0.098	NS	-0.089,0.021
	Pack year	-0.168	0.043	-0.178	***	-0.254,-0.082
	Low vs. high	-3.513	0.211	-0.768	***	-3.929,-3.097
Δ FEF_{25-75}% **R^2=0.32**	Constant	0.692	1.879		NS	-3.013,4.398
	Age	-0.019	0.043	-0.047	NS	-0.103,4.398
	BMI	0.058	0.058	0.06	NS	-0.056,0.173
	DUR. work	-0.034	0.05	-0.073	NS	-0.132,0.065
	Pack year	-0.225	0.078	-0.177	**	-0.378,-0.072
	Low vs. high	-3.393	0.377	-0.552	***	-4.137,-2.649

Δ indices= [(post shift index – pre shift index)/pre shift index] *100. NS (not significant)

Low vs. high (0=low exposed, 1=high exposed), R^2: adjusted square of the correlation coefficient.

B: regression Coefficient, SE: standard error of the regression coefficient. 95% CI: 95% confidence interval. ** P<0.01; ***P<0.001

Multivariate linear regression analysis with cement exposure, Age, BMI, Duration work and number of pack-years as independent variables, showed that cement exposure and pack year were negatively associated with spirometric indices especially with ΔPEF and Δ FEV1 (Table 4).

The negative effect of cement exposure suggests that being in high exposed group associated with a decrease in ΔPEF of -7.17 (95% CI= -8.024 to -6.324) and in ΔFEV1 of -3.51(-3.929, -3.097) with R^2=0.61 (Table 4). Although the prevalence of smoking among the workers was generally unremarkable, we observed negative effect of pack year on cross-shift changes , as each pack year associated with cross shift decrease of (-0.297) in Δ PEF and (-0.225)in Δ FEF25-75.Age, BMI and duration of work were not significantly associated with cross-shift changes in the multilinear regression.

Discussion

In this study, the total dust concentration for the workers in high exposed area was significantly higher than the low exposed area as the office workers were in constructions 300 meters from the production area. Furthermore, the measured total dust levels were highest in the crusher and packing sections. This is in accordance with a previous study reporting the highest geometric mean dust exposure in the crusher and packing sections. Although 40% of workers in high exposed area reported wearing disposable facemasks, 80% of them have reported that masks were not provide adequate protection in reducing dust exposure .This is higher compared with conditions in a cement plant in Ethiopia that only 15% uses masks (10). It has been shown that exposure to Portland cement dust without any respiratory protection lead to obstructive impairment (14); therefore, regular use of high quality personal protective respiratory equipment is recommended. The high exposed group had significantly higher prevalence for acute respiratory symptoms than the low exposed group. This is most likely due to the high concentration of dust in the working environment and may be related to the irritative reactions caused by the cement dust.

These results were in agreement with zelek *et al*. (10) Alvear Galindo *et al* (29) and Mwaiselage *et al* (7) whom all found a higher prevalence of acute respiratory symptoms among exposed cement workers. Mwaiselage *et al*(7) also demonstrated a possible exposure-symptom relationship when comparing workers with exposure ≥ 2 mg/m3 of cement dust versus <2 mg/m3 for cough and shortness of breath. However, a cohort study in Norway (19) has shown no differences in respiratory symptoms between exposed cement workers with matched blue-collar controls.

In this present study, we observed a cross-shift reduction in PEF, FEV1, FEF25-75, FVC and FEV1/FVC% among the high exposed workers. Our finding of the cross-shift decrease in PEF is in agreement with the result of previous cross-shift studies among worker exposed to higher levels of dust (7, 10). Our findings are also similar to those of Ali BA *et al* (30) who found a significantly post-shift reduction in FEV1, FEV1/FVC% and FEF25-75 in the exposed subjects. Fell AK *et al* (24) also detected small cross-shift changes in lung function among cement production workers at exposure levels below 1 mg/m3 .However the observed difference in magnitude of spirometric indices changes in these studies might be due to different total and respirable dust concentration and different type of dust sampling.

We did not study the duration of the effect of exposure. This should be evaluated further in future studies with the evaluation of the functional indices the day after the work shift. Also, we did not measure changes in spirometric indices for evening and night shifts. The finding by AbuDhaise and coworkers(11) in a cross sectional survey of cement workers which showed no markedly difference in spirometric indices between higher, medium and lower exposure groups is contradicted with the results of several studies suggesting significantly lower spirometry indices among exposed workers(5, 13, 14, 18, 22).

Higher per shift spirometric indices in high exposed groups might be due to their young age. The increase in indices for the office worker across the shift might be due to normal diurnal changes. This circadian influence is shown to cause an increase in FVC, FEV1 and PEF between 9:00 Am and noon (31).

In the multivariate linear regression model being in high exposed group and number of pack year were associated with an increased percentage of cross shift decrease in PEF. Zelek *et al* (10) and Mwaiselage *et al* (7) found that total dust exposure and the cross-shift decrease in PEF were significantly related, similar to our findings. In another study Ali BA *et al* (30) also found a relationship between post shift changes and exposure to cement dust; however failed to support any association with smoking or duration of service. Several previous studies showed that smoking and the number of pack years were not significantly associated with spirometric indices in the multiple linear regressions (7, 10, 30). This might be due to low prevalence of smokers in these studies.

In our studies, the prevalence of smoking among the workers was 18% with pack year range of 0-15 and the observed negative effect of pack year suggests that smokers react more to the acute dust exposure; however, further longitudinal studies are warranted to elucidate the effect of smoking.

This study showed a significant relationship between exposure to the high concentration of cement dust and acute respiratory symptoms and cross shift reduction in spirometric indices.

The acute respiratory health effect can presumably be reduced by effective dust-control measures at workplace, implementation of respiratory protective equipment program, supply of high – quality facemasks, reduction or elimination of smoking by the exposed workers and management in defining essential strategies for early identification and monitoring worker with impaired ventilatory function.

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