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ORIGINAL ARTICLE

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Acute respiratory health effects among cement factory workers in Tanzania: an evaluation of a simple health surveillance tool

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Abstract *Objectives*: The effects of cement dust exposure on acute respiratory health were assessed among 51 high exposed and 33 low exposed male cement workers. The ability of the questionnaire to diagnose acute decrease in ventilatory function was also assessed. *Methods*: Acute respiratory symptoms were recorded by interview using a structured optimal symptom score questionnaire. Peak expiratory flow (PEF) was measured preshift and post-shift for each worker with a Mini-Wright PEF meter. Personal respirable dust ($n=30$) and total dust ($n=15$) were measured with 37-mm Cyclone and 37-mm closed-faced Millipore cassette. Twenty-nine workers had concurrent respirable dust, PEF and questionnaire on the same day. *Results*: The geometric means of personal respirable dust and total dust among high exposed were 4.0 and 13.2 mg/m^3, respectively, and 0.7 and 1.0 mg/m^3 among low exposed. High exposed workers had more acute cough, shortness of breath and stuffy nose than the low exposed. Mean percentage cross-shift decrease in PEF was significantly more pronounced among high exposed workers than low exposed (95% CI 1.1, 6.1%). For workers with concurrent respirable dust, PEF and questionnaire assessment, an exposure–response relationship was found between log-transformed respirable dust and percentage cross-shift decrease in PEF (4.5% per unit of log-respirable dust in mg/m^3 ; 95% CI 3.3, 5.6%). Respirable dust exposure ≥2.0 mg/m^3 versus <2.0 mg/m^3 was associated with increased prevalence ratio for cough (7.9) and shortness of breath (4.2). Shortness of breath was associated with the highest sensitivity (0.87) and specificity (0.83) for diagnosing a percentage cross-shift decrease in PEF of ≥10%. *Conclusion*: The observed acute respiratory health effects among the workers are most likely due to exposure to high concentrations of irritant cement dust. The results also highlight the usefulness of the questionnaire for health surveillance of the acute respiratory health effect.

Keywords Cement dust · Exposure–response relationship · Health surveillance · Peak expiratory flow rate (PEF) · Respiratory symptoms

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Introduction

The major pollution problem in the cement industry is dust, which is emitted from various parts of the production process such as the raw material crusher, rotary kiln, cranes, mills, storage silos and packing sections (ILO 1999). Airborne respirable dust levels from less than 5 to more than 40 mg/m^3 have been recorded in the workplace air of cement factories (Fairhurst et al. 1997). The aerodynamic diameter of the cement dust ranges from 0.05 to 20 μm, making the whole respiratory tract a target for cement deposition (Oleru 1984). The essential constituents of Portland cement are tricalcium silicate and dicalcium silicates, with varying amounts of alumina, tricalcium aluminate and iron oxide and low concentrations of hexavalent chromium (Fairhurst et al. 1997). Workers exposed to cement dust have chronic respiratory symptoms (Oleru 1984; Alakija et al. 1990; Noor et al. 2000; Abou-Taleb et al. 1995), chronic impairment of ventilatory function (Oleru 1984; Alakija et al. 1990 Noor et al. 2000; Mengesha and Bekele 1997) and chronic lung and pleural abnormalities on chest radiography (Abrons et al. 1997). Occupationally related respiratory cancer has also been reported (Jakobsson et al. 1993; Dietz et al. 2004).

Deposition of cement dust in the respiratory tract causes a strong basic reaction leading to increased pH values (12.5–13.0) that irritate the exposed mucous membranes (Fairhurst et al. 1997; Dietz et al. 2004). Furthermore, calcium and aluminum found in cement dust have been shown to irritate mucous membranes (ACGIH 2000). Crystalline silica exposure is associated with the development of respiratory health effects (Ulvestad et al. 2001), however in cement dust the concentration of airborne respirable silica has been reported to be low (Abrons et al. 1988; Fell et al. 2003). Previous studies of respiratory health among cement workers have focused mainly on chronic effects from the dust. A few studies suggest that acute exposure to cement dust may have immediate effects on the ventilatory function, but the results are not clear because there has been no report on acute exposure–response relationship (Mengesha and Bekele 1997; Ali et al. 1998). The primary aim of a surveillance strategy at work places is to ensure adequate worker protection by identifying cases of occupational disease as early as possible. Both dust sampling and health examinations are often suggested to be part of surveillance programs in the industry (ILO 1999). However, dust sampling and ventilatory function assessments are rather expensive methods for surveillance particularly in developing countries, whereas the use of questionnaires demands less resource. A comparison of results from a respiratory questionnaire with a more objective criterion of ventilatory function assesses validity of the questionnaire as expressed by sensitivity and specificity. A high sensitivity indicate a high true positive rate and a low false negative rate, while a high specificity indicate a high true negative rate and a low false positive rate. If clear relationships exist between current dust levels, acute respiratory symptoms and ventilatory function, health surveillance by questionnaire might be a useful tool.

The aim of this study was to investigate the association between current cement dust exposure and acute respiratory effects among cement factory workers in Tanzania. Another aim was to investigate the relationship between acute respiratory symptoms and acute ventilatory function impairment in order to evaluate a method for health surveillance.

Materials and methods

Setting

The study was conducted at a Portland cement factory in Dar Es Salaam, Tanzania between June–August 2001. The factory was established in 1965 and produces about 500,000 tons of cement per year and employs about 300 workers.

Study groups

Based on preliminary information, the workers were classified into two exposure groups according to the estimated exposure to cement dust. The high exposed group comprised production department workers, and the low exposed group comprised workers in the maintenance department and administration building. The production workers are divided into 6 sections: crusher ($n=20$), crane ($n=15$), raw mill ($n=17$), kiln ($n=30$), cement mill ($n=12$) and packing ($n=32$). The raw mill and cement mill sections were not involved because they were expected to have lower exposures than the other high dust-exposed sections. The low exposed group comprised office workers from a three-floor administration building ($n=55$); and maintenance workers comprising mechanics ($n=44$) and electricians ($n=24$). Male workers in the crusher ($n=13$), crane ($n=11$), kiln ($n=15$) and packing ($n=14$) were selected consecutively using a payroll list as the high exposed workers. Male workers in the administration ($n=17$) and maintenance ($n=17$) were picked out consecutively using a payroll list as the low exposed workers. The overall study population comprised 53 exposed production workers and 34 controls. This sample size provided 90% power to detect difference of 15 l/min between the groups for paired observation of peak expiratory flow (PEF) rate and for a difference in the acute respiratory symptom score of 2 between the groups, both at $P<0.05$. The ethical committees of West Norway and Tanzania approved the study, and permission to conduct the study was granted by the factory management. All participants gave informed consent after the purpose and methods of the study were clearly explained.

Exposure to cement dust

Personal exposure in the breathing zone was measured by sampling respirable dust ($n=30$) and total dust ($n=15$) among randomly chosen workers from the study population. Respirable dust was collected on preweighed cellulose acetate filters with a pore size of 0.8 μm placed in a 37-mm cyclone (Cassella, London, UK) connected to an SKC sidekick pump with a flow rate of 1.9 l/min. Total dust was collected on preweighed cellulose acetate filters with a pore size of 0.8 μm placed in a closed-faced 37-mm filter cassette (Millipore, Millipore Corporation, Bedford, MA, USA) connected to an SKC sidekick pump with a flow of 2.0 l/min. Sampling was performed during the day shift over 8 weeks; the sampling time varied from 360 to 480 min. The cement dust collected was measured quantitatively by gravimetric analysis using a Mettler microbalance (AT261) with a sensitivity of 0.05 mg. One respirable dust sample was not analyzed because the pump had stopped during sampling. Personal exposure data were log-normally distributed and the natural logarithms of exposure were used in the analysis. Six total dust samples were analyzed for calcium, aluminium, chromium, iron, magnesium, sodium, potassium, barium, manganese, nickel, lead, zinc, strontium and copper using inductively coupled plasma–atomic emission spectrometry (ARL 3410+, Thermo

ARL, Valencia, CA, USA). The samples chosen for analysis of elements were those with the highest levels of total dust from crusher ($n = 3$) and packing ($n = 3$). The analysis was performed at X-lab AS (Bergen, Norway), which has passed the Norwegian intercalibration test for dust sample analysis. Three respirable dust samples with the highest levels in the crusher, cranes and the packing sections were analyzed at the SGAB analytical laboratory in Luleå, Sweden for crystalline silica (alpha-quartz) content by X-ray diffraction using NIOSH method 7500 (NIOSH 1998).

Assessment of respiratory health effects

Questionnaire interview

A single investigator conducted the interviews using a respiratory symptom score questionnaire which was developed by modifying previous questionnaires from the literature (BMRC 1960; Wasserfallen et al. 1997). This questionnaire included data on sociodemographic characteristics, occupational history, utilization of respiratory protective gear, smoking habits (current smokers and non-smokers) and severity of acute respiratory symptoms of cough, shortness of breath, stuffy nose, wheeze, runny nose and sneezing. At the end of the 8-hour day shift, the acute respiratory symptoms occurring were scored and recorded on a five-point Likert scale as never (1), mild (2), moderate (3), severe (4) or very severe (5).

Ventilatory tests

Peak expiratory flow was measured preshift and post-shift for each worker in an office near the workers' main entrance. The measurements were performed with the workers in standing position by using a portable hand-held Mini-Wright PEF meter operated by the same investigator who did the interviews. Each worker was measured three times, and the highest value was used as the final result (Hauser et al. 1996). Height in centimeter and weight in kilograms was also measured. The acute cross-shift change in PEF expressed in percentage was calculated as [(preshift PEF–postshift PEF)/preshift PEF]×100. Overall, 30 workers had concurrent respirable dust, PEF and questionnaire assessment on the same day.

Statistical analysis

The data sets were analyzed using SPSS (Chicago, IL, USA) version 11.0 for Windows. Data are expressed as mean (standard deviation) and number (percentage). Comparison of acute respiratory symptoms score and dust levels between the groups were performed using Mann-Whitney test because the assumptions for normal distribution were not met. During further analysis, the acute respiratory symptom scores of 2–5 indicated an event (symptom) has occurred while a score of 1 indicated no event (symptom). Comparisons of each acute respiratory symptom between the groups were determined using Cox regression model (Thompson et al. 1998). In this model, the duration of the 8-h shift was used as the time-to-event. The differences in PEF indices between the groups were determined by multiple linear regressions. In both regression analyses, adjustments were made for age, duration of employment and education (primary versus postprimary) as these variables differed between the two groups. The sensitivity and specificity of each acute respiratory symptom to detect a ≥10% cross-shift decrease in PEF were calculated as described by Hennekens and Buring (1987). A decrease in PEF of ≥10% indicates a marked effect of the dust on the respiratory airways (Massin et al. 1991).

For 29 workers with concurrent respirable dust, PEF and questionnaire measurements on the same shift, univariate regressions were used to identify the potential determinants for the percentage decrease in PEF and acute respiratory symptoms. The potential determinants analysed were age, employment duration, height, facemask use, smoking habit, education level and dust levels. The exposure-PEF relationship was analysed by multiple linear regression while adjusting for age and employment duration. Cox regression was used to assess the effect of respirable dust (< 2.0 vs. ≥ 2.0 mg/m^3) on acute respiratory symptoms while adjusting for employment duration. The median respirable dust concentration for all the samples was 2.03 mg/m^3, and thus 2.0 mg/m^3 was used as the cut-off point. In the exposure–response regression models, smoking habit although was not a significant determinant, was included because it is a known confounder. Statistical significance was accepted at the $P \leq 0.05$ level.

Results

Occupational dust exposure

For the high exposed workers, the geometric means (GM) of the respirable and total dust were 4.0 mg/m^3 and 13.2 mg/m^3, respectively (Table 1). About 37.5% (9/24) of the respirable dust samples exceeded the occupational exposure limit (OEL) of 5 mg/m^3, whereas 54.5% (6/11) of the total dust samples exceeded the OEL of 10 mg/m^3 (Fairhurst et al. 1997). The corresponding GM dust concentrations for low exposed workers (0.66 mg/m^3 and 1.03 mg/m^3) were significantly lower ($P < 0.001$ in both cases), and none of these samples exceeded the OEL. The concentrations of alpha-quartz were 0.004 mg/m^3 (crane), 0.004 mg/m^3 (packing) and 0.170 mg/m^3 (crusher) in the three selected respirable dust samples, representing 0.01%, 0.02% and 0.24% of the respirable dust in the respective samples. The six

Table 1 Personal sampled respirable dust ($n=29$) and total dust ($n=15$) concentrations among high exposed and low exposed cement factory workers

Section	n	Cement dust levels		
		Median (range) (mg/m^3)	AM (SD)[a] (mg/m^3)	GM (GSD)[b] (mg/m^3)
High exposed group				
Respirable dust				
All	24	2.7 (0.7–71.2)	10.6 (19.6)	4.0 (3.5)
Crusher	7	12.0 (1.5–70.2)	19.3 (24.9)	8.0 (4.7)
Packing	6	4.2 (2.0–20.8)	7.9 (6.6)	4.3 (1.8)
Cranes	7	2.0 (1.7–71.2)	12.8 (3.7)	3.6 (3.9)
Kiln	4	1.2 (0.7–3.0)	1.5 (1.1)	1.3 (1.9)
Total dust				
All	11	23.9 (1.5–158.0)	32.9 (46.3)	13.2 (4.6)
Crusher	4	19.5 (2.3–158.0)	49.8 (73.0)	17.8 (6.0)
Packing	4	30.6 (23.9–75.6)	38.9 (21.8)	35.1 (1.6)
Kiln	3	2.7 (1.5–3.5)	2.6 (0.9)	2.4 (1.5)
Low exposed group				
Respirable dust				
All	5	0.6 (0.4–1.8)	0.8 (0.6)	0.7 (0.6)
Total dust				
All	4	1.1 (0.4–2.5)	1.3 (0.9)	1.0 (2.3)

[a]Arithmetic mean (standard deviation)
[b]Geometric mean (geometric standard deviation)

total dust samples analyzed for elements had a median concentration of 33.1 mg/m^3 (range: 23.9–158.0). The results in milligram per cube metre were (median; range): calcium (1.3; 0.2–6.0), followed by aluminum (0.2; 0.01–0.2), iron (0.01; 0.005–0.2) and potassium (0.01; 0.001–0.04). The median concentrations of other elements were relatively small (<0.01 mg/m^3).

High exposed versus low exposed

General characteristics

Of 87 workers selected to participate, 84 completed the questionnaire and the ventilatory test: 51 high exposed workers and 33 low exposed workers. The high exposed workers were significantly younger and had worked for fewer years than the low exposed workers (Table 2). The two groups did not differ significantly in smoking habits, height or weight (Table 2). Most low exposed workers had postprimary education (secondary, college or university) (Table 2). A total of 21 (41.2%) of the high exposed workers reported using disposable personal respiratory filter masks during their particular 8-h work shift. These facemasks were of poor quality and were used repeatedly. Documentation of the filter type was not accessible.

Acute respiratory symptoms and ventilatory tests

The high exposed workers had significantly higher scores for all the acute respiratory symptoms than the low exposed workers (Table 2). The high exposed workers had significantly higher adjusted prevalence ratio (PR; 95% confidence interval (CI)) than the low exposed workers for cough (6.7; 1.6–29.3), shortness of breath (4.5; 1.3–15.4) and stuffy nose (1.9; 1.0–3.6) (Table 3). No worker in any group reported wheezing. The two groups did not differ in preshift PEF, but the high exposed group had significantly lower postshift PEF than the low exposed group (Table 3). The percentage cross-shift decrease in PEF was significantly higher in the high exposed group

Table 2 General characteristics and acute respiratory symptoms score of the 84 male cement factory workers categorized into high exposed and low exposed groups

	High exposed ($n=51$)	Low exposed ($n=33$)	P	29 workers[g]
Age (years)[a]	34.8 (8.8)	39.4 (6.2)	0.007[c]	34.8 (8.9)
Employment (years)[a]	11.1 (8.0)	14.5 (7.6)	0.048[c]	11.0 (7.7)
Height (cm)[a]	169.2 (6.8)	169.3 (7.6)	0.960[c]	168.7 (5.1)
Weight (kg)[a]	71.2 (13.3)	75.6 (14.4)	0.165[c]	68.6 (11.6)
Education level[b]				
Primary	30 (58.8)	5 (15.2)	<0.001[d]	17 (58.6)
Postprimary	21 (41.2)	28 (84.8)		12 (41.4)
Smoking habits[b]				
Non-smokers	46 (90.2)	32 (96.9)	0.648[d]	25 (86.2)
Current smokers	5 (9.8)	1 (3.0)		4 (13.8)
Cough score[f,a]	1.5 (0.6)	1.1 (0.2)	0.001[e]	1.6 (0.7)
Shortness of breath score[f,a]	1.6 (0.7)	1.1 (0.3)	0.001[e]	1.6 (0.8)
Stuffy nose score[f,a]	2.2 (0.8)	1.4 (0.6)	< 0.001[e]	2.0 (0.9)
Runny nose score[f,a]	1.6 (0.9)	1.2 (0.5)	0.017[e]	1.7 (0.9)
Sneezing score[f,a]	1.9 (0.9)	1.4 (0.6)	0.005[e]	1.7 (0.9)

[a]Mean (standard deviation)
[b]Number (%)
[c]Independent t test
[d]Chi-square test
[e]Mann-Whitney test
[f]Symptom score (1 = never, 2 = mild, 3 = moderate, 4 = severe, 5 = very severe)
[g]Workers with concurrent respirable dust, PEF and questionnaire measurements on the same shift

(mean 7.6%) than in the low exposed group (mean 2.7%; Table 3).

PEF-symptom relationship

Workers with cough or shortness of breath had a significantly higher probability of having a ≥10.0% decrease in PEF (Table 4). The highest sensitivity and specificity was found when diagnosing the ≥10% decrease in PEF by shortness of breath (Table 4). Stuffy nose, runny nose and sneezing had no association with the 10% decrease in PEF (Table 4).

Workers with concurrent measurements

Exposure-PEF relationship

A significant exposure–response relationship was found between the log-transformed respirable dust and percentage cross-shift decrease in PEF values (4.5% per unit of log-transformed dust level in mg/m^3; Table 5). The negative effect of age suggests that younger subjects reacts more to the acute dust exposure than older ones (Table 5).

Exposure–symptom relationship

Workers who had respirable dust exposure ≥2.0 mg/m^3 had a higher adjusted PR (95% CI) for cough (7.9; 1.8–35.6) and shortness of breath (4.2; 1.1–15.4) than workers who had exposure $<$2.0 mg/m^3 (Table 6).

Discussion

The measured exposure levels should be interpreted with care because few samples were taken in each section. Nevertheless, the workers and their supervisors reported that the production and the work tasks on the days of dust sampling were representative for normal working days. The total dust concentration for the exposed workers was higher than found in studies of cement workers in United States (GM: 2.9 mg/m^3; Abron et al. 1988), Norway (AM: 7.4 mg/m^3; Fell et al. 2003) and Denmark (median: 3.3 mg/m^3; Vestbo and Rasmussen 1990). This probably reflects newer machinery and a higher level of dust control in the work areas in industrialized countries. Our levels are higher than those in Malaysia (GM: 10.2 mg/m^3; Noor et al. 2000) but lower than those in Nigeria (GM: 30.81 mg/m^3; Oleru 1984). However, Oleru averaged only four 30-minute samples. The concentration of respirable dust for the exposed group is comparable to those in Taiwan (GM: 3.6 mg/m^3; Yang et al. 1996) and Jordan (GM: 3.9 mg/m^3; AbuDhaise et al. 1997) but higher than those in Denmark (median: 1.5 mg/m^3; Vestbo and Rasmussen 1990), Norway (AM: 0.9 mg/m^3; Fell et al. 2003) and the United States (GM: 0.57 mg/m^3; Abrons et al. 1988). The concentrations of alpha-quartz in the respirable dust samples are in the same range as those in Norway (range: $<$0.01–0.06 mg/m^3; Fell et al. 2003) and United States (median: 0.079 mg/m^3; Abron et al. 1988).

The high exposed group had significantly more acute respiratory symptoms than the low exposed group. This is most likely due to the high concentration of dust in the work environment and probably to specific components in the cement dust. Calcium, which had the highest elemental concentration in dust samples, directly irritates the respiratory passages (ACGIH 2000) and might be important in causing acute respiratory symptoms. The results of the acute respiratory symptoms are in agreement with Alvear Galindo et al. (1999) who found a higher prevalence of record-based "acute upper respiratory tract diseases" among the cement workers. However a study in Norway (Fell et al. 2003) found no difference in "symptoms during work" between cement

Table 3 Acute respiratory symptoms and peak expiratory flow rates (PEF) indices among 84 male cement factory workers categorized into high exposed and low exposed groups

	High exposed $n=51$	Low exposed $n=33$	P		29 workers[h]
Cough[a]	21 (41.2)	2 (6.0)	0.011[c]	6.7 (1.6, 29.3)[e]	15 (51.7)
Shortness of breath[a]	22 (43.1)	3 (9.1)	0.017[c]	4.5 (1.3, 15.4)[e]	13 (44.8)
Stuffy nose[a]	40 (78.4)	13 (39.4)	0.050[c]	1.9 (1.0, 3.6)[e]	18 (62.1)
Runny nose[a]	20 (39.2)	5 (15.1)	0.094[c]	2.4 (0.9, 6.6)[e]	13 (44.8)
Sneezing[a]	31 (60.8)	11 (33.3)	0.288[c]	1.5 (0.7, 3.1)[e]	15 (51.7)
Preshift PEF (l/min)[b]	447.8 (48.7)	458.2 (75.5)	0.473[d]	−39.1, 18.3[f]	438.9 (40.9)
Postshift PEF (l/min)[b]	414.3 (56.7)	446.9 (58.3)	0.012[d]	−69.3, −8.9[f]	407.9 (62.9)
Percentage PEF decrease[g,b]	7.6 (5.5)	2.7 (4.6)	0.006[d]	1.1, 6.1[f]	7.5 (7.2)

[a]Number (%)
[b]Mean (standard deviation)
[c]Cox regression adjusted for age, employment duration and education level
[d]Multiple linear regression adjusted for age, employment duration and education level
[e]Prevalence ratio (PR) [95% confidence interval (CI)]
[f]95% CI
[g][(Preshift PEF–postshift PEF)/preshift PEF]×100
[h]Workers with concurrent respirable dust, PEF and questionnaire measurement on the same shift

Table 4 Association between acute respiratory symptoms and the percentage cross-shift decrease in PEF among the 84 cement workers expressed as number (%)

	< 10.0% decrease ($n = 69$)	≥10.0% decrease ($n = 15$)	P^a	Sensitivity (95% CI)	Specificity (95% CI)
Cough	13 (18.8)	10 (66.7)	0.001	0.67 (0.43, 0.91)	0.81 (0.71, 0.91)
Shortness of breath	12 (17.4)	13 (86.7)	< 0.001	0.87 (0.69, 1.00)	0.83 (0.73, 0.93)
Stuffy nose	43 (62.3)	10 (66.7)	0.780	0.67 (0.43, 0.91)	0.38 (0.26, 0.49)
Runny nose	17 (24.6)	8 (53.3)	0.058	0.53 (0.26, 0.80)	0.75 (0.65, 0.85)
Sneezing	33 (47.8)	9 (60.0)	0.570	0.60 (0.35, 0.85)	0.52 (0.40, 0.63)

Specificity = workers with "absent" acute symptom/workers with < 10% change in PEF. 95% confidence interval = 95% CI[a]Fisher's exact test. Sensitivity = workers with "present" acute symptom/ workers with ≥10% change in PEF

workers and blue-collar controls, but the dust levels in their study were relatively low. We also observed a possible exposure–symptom relationship when comparing workers with exposure ≥2.0 mg/m^3 versus < 2.0 mg/m^3 for cough and shortness of breath. There was no significant exposure–symptom relationship for nasal symptoms. This probably suggests that nasal symptoms are not specifically associated with dust exposure. Because of small sample size and high prevalence of the symptoms, the PR obtained using Cox regression was appropriate in examining the exposure–symptom relationship (Thomson et al. 1998). Although 41.2% of the high exposed workers in the present study reported using facemask, they were observed not to wear them during the whole shift. Furthermore, these masks were of poor quality and were presumably not very effective in reducing dust exposure.

The mean percentage cross-shift decrease in PEF was more pronounced among high exposed workers than among low exposed. This is in agreement with previous cement studies (Mengesha and Bekele, 1997; Ali et al. 1998). The decrease in PEF was presumably not due to normal circadian changes, as this would have caused a slight increase in PEF (Lebowitz et al. 1997). Some studies in other industries have shown larger decreases in PEF for evening and night shifts than for day shifts (Lebowitz et al. 1997; Zock et al. 1999). However, we did not measure PEF on the different shifts. The exposure-PEF regression equation predicts that, the percentage cross-shift decrease in PEF would be 10.8% for a worker exposed to an average of 10.6 mg/m^3 respirable dust during the shift.

The BMRC questionnaire contains few items for eliciting acute respiratory symptoms. Consequently, our study supplemented the BMRC questionnaire with items on acute respiratory symptoms for eliciting severity. The dichotomization of the five-point symptom scores into "present" and "absent" is an oversimplification and might have resulted in loss of information giving a cruder outcome. However, dichotomization was necessary based on conditions of Cox regression whereby an event of a status variable needs to be identified. Furthermore, the interval between the scale points in the symptom score was not expected to be even, thus logical analyses were preferred options.

A decrease in PEF of ≥10% was significantly associated with acute cough and shortness of breath. Our findings are in agreement with a previous study in automotive plant suggesting a strong positive relationship between acute lung function change and respiratory symptoms (Robins et al. 1997). Sensitivity of a screening test is the probability that an individual with the disease will have a positive test, while specificity is the probability that an individual without the disease will have a negative test. In this present study, shortness of breath had a sensitivity of 87% and a specificity of 83% in determining the presence of ≥10% decrease in PEF. This indicates high true positive and true negative rates. Therefore, shortness of breath seems to be a relatively useful symptom for predicting a > 10% cross-shift decrease in PEF in the factory. Sensitivity and specificity values offer a simplified method of assessing the usefulness of a screening test. Positive and negative predictive values are also useful tests, but these vary with

Table 5 Association between current respirable dust exposure and percentage cross-shift decrease in PEF (ΔPEF%) among 29 cement workers

	Covariates	B	SE	P	95% CI
ΔPEF% (R^2 adjusted = 0.71)	Constant	11.2	6.4	0.093	−2.0, 24.4
	Age (years)	−0.4	0.2	0.017	−0.8, −0.1
	Employment duration (years)	0.5	0.2	0.013	0.1, 0.9
	Smoking(0 = no; 1 = yes)	0.6	2.2	0.782	−3.9, 5.2
	Log-respirable dust (mg/m^3)	4.5	0.6	< 0.001	3.3, 5.6

Workers who had concurrent respirable dust, PEF and questionnaire on the same shift

PEF peak expiratory flow rate, *B* regression coefficient, *SE* standard error of regression coefficient, Δ PEF% = (preshift PEF–postshift PEF)/preshift PEF×100; 95% CI = 95% confidence interval

Table 6 Association between acute respiratory symptoms and the respiratory dust categories among 29 cement workers expressed as number (%)

	< 2.0 mg/m^3 (n = 14)	≥ 2.0 mg/m^3 (n = 15)	P[a]	PR (95% CI)[b]
Cough	2 (14.3)	13 (86.7)	0.007	7.9 (1.8, 35.3)
Shortness of breath	3 (21.4)	10 (66.7)	0.033	4.2 (1.1, 15.4)
Stuffy nose	8 (57.1)	10 (66.7)	0.403	1.5 (0.6, 3.9)
Runny nose	5 (35.7)	8 (53.3)	0.274	1.9 (0.6, 5.9)
Sneezing	7 (50.0)	8 (53.3)	0.594	1.3 (0.5, 3.8)

Workers who had concurrent respirable dust, PEF and questionnaire measurements on the same shift
[a]Cox regression adjusted for employment duration and smoking
[b]Prevalence ratio (95% confidence interval)

the disease prevalence and are potentially meaningful when the disease prevalence is low. No worker in any group reported wheezing. Some studies have reported similar findings and suggested that workers or asthmatics may deny the presence of wheezing even if it is audible (Burge 1997). Furthermore, the wheeze symptom may occur much later in the development of disease and after a substantial decrease in PEF (≥20%) (Bohadana et al. 1994).

A health surveillance technique for early detection of abnormality related to occupational exposure should be sensitive, specific, easy to perform and interpret, safe and non-invasive. Both, questionnaire and PEF monitoring are relative inexpensive methods for screening acute respiratory health effects in occupational settings. However, PEF consume more time; require height measurements, disposable mouthpieces and regular check for wear and tear. Thus, our optimal symptom score questionnaire can be a useful tool for health surveillance and research of acute respiratory effects in dusty industries particularly in developing countries where funding is limited. An important complement to a surveillance program is measurements of the exposures in the workplace. However, resources in the developing countries also limit this option. Although acute effects are not necessarily disabling, they may cause significant discomfort that results in temporary disability and also may be indicative of a more serious impairment. Thus, acute health effects due to dust exposure should not be accepted to occur in an occupational setting. Further studies with larger sample size are needed to confirm the validity of the questionnaire in industries with variable exposure.

Smoking was not significantly associated with the PEF indices or with the acute respiratory symptoms. The reason could be the low prevalence of smokers, as also reported by Oleru (1984) or because of young age of the studied workers or because current smoking is not associated with short-term PEF impairment. About 96% of those selected to participate attended the examination; and the data therefore have high internal validity. The small sample size used in our study, particularly in the exposure–response analysis, might have led to less precise estimates. In this present study, confounder were adjusted for, thus the observed exposure–response relationships presumably reflect the effects of dust exposure.

Effective dust-control measures at the workplace will presumably reduce acute respiratory health effects. Supplying high-quality personal respiratory protective equipment accompanied with supervision will probably benefit the individual factory workers. Our study provides evidence of the utility of the respiratory symptom score questionnaire for assessing acute ventilatory impairment associated with cement dust exposure.

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References

Abou-Taleb AN, Musaiger AO, Abdelmoneim RB (1995) Health status of cement workers in the United Arab Emirates. J R Soc Health 115(6):378–381

Abrons HL, Petersen MR, Sanderson WT, Engelberg AL, Harber P (1988) Respiratory symptoms, ventilatory function, and environmental exposures in Portland cement workers. Br J Ind Med 45:368–375

Abrons HL, Petersen MR, Sanderson WT, Engelberg AL, Harber P (1997) Chest radiography in Portland cement workers. J Occup Environ Med 39(11):1047–1054

AbuDhaise BA, Rabi AZ, Al Zwairy MA, El Hader AF, El Qaderi S (1997) Pulmonary manifestations in cement workers in Jordan. Int J Occup Med Environ Health 10(4):417–428

Alakija W, Iyawe VI, Jarikre LN, Chiwuzie JC (1990) Ventilatory function of workers at Okpella cement factory in Nigeria. West Afr J Med 9(3):187–192

Ali BA, Ballal SG, Albar AA, Ahmed HO (1998) Post-shift changes in pulmonary function in a cement factory in eastern Saudi Arabia. Occup Med 48(8):519–522

Alvear Galindo MG, Mendez-Ramirez I, Villegas-Rodriguez JA et al (1999) Risk indicator of dust exposure and health effects in cement plant workers. J Occup Environ Med 41(8):654–661

American Conference of Governmental Industrial Hygienists (ACGIH) (2000) Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: ACGIH, pp 15–76

Bohadana AB, Massin N, Teculescu D, Peslin R (1994) Tracheal wheezes during metacholine airway challenge (MAC) in workers exposed to occupational hazards. Respir Med 88(8):581–587

British Medical Research Council's committee (BMRC) (1960) Standardised questionnaire on respiratory symptoms. Br Med J 2:1665

Burge PS (1997) The relationship between peak expiratory flow and respiratory symptoms. Eur Respir J 10(suppl 24):67s–68s

Dietz A, Ramroth H, Urban T, Ahrens W, Becher H (2004) Exposure to cement dust, related occupational groups and laryngeal cancer risk: results of a population based case-control study. Int J Cancer 108:907–911

Encyclopaedia of occupational health and safety (1999) 4th edn, vol 3. International Labour Organization, Geneva, pp 93.44–93.46

Fairhurst S, Phillips A, Gilles C, Brown RH (1997) Portland cement dust: criteria document for an occupational exposure limit. Health and Safety Executive, London

Fell AK, Thomassen TR, Kristensen P et al (2003). Respiratory symptoms and ventilatory function in workers exposed to Portland cement dust. J Occup Environ Med 45(9):1008–1014

Hauser R, Daskalakis C, Christiani D (1996) A regression approach to the analysis of serial peak flow among fuel oil ash exposed workers. Am J Respir Crit Care Med 154:974–980

Hennekens CH, Buring JE (1987) Epidemiology in Medicine, 1st edn. Little, Brown and co., USA, pp 331–345

Jakobsson K, Horstmann V, Welinder H (1993) Mortality and cancer morbidity among cement workers. Br J Ind Med 50(3):264–272

Lebowitz MD, Krzyzanowski M, Quackenboss JJ, O'Rourk MK (1997) Diurnal variation of PEF and its use in epidemiological studies. Eur Respir J 24(suppl):49s–56s

Massin N, Moulin JJ, Wild P et al (1991) A study of the prevalence of acute respiratory disorders among workers in the textile industry. Int Arch Occup Environ Health 62(8):555–560

Mengesha YA, Bekele A (1997) Effects of acute exposure to different occupational dusts on pulmonary function indices of factory workers in Ethiopia. Afr Newslett Occup Health Saf 7:8–9

National Institute for Occupational Safety and Health (NIOSH) (1998) Manual of Analytical Methods. Silica, Crystalline, by XRD Method 7500, 4th edn. Cincinnati, NIOSH

Noor H, Yap CL, Zolkepli O, Faridah M (2000) Effects of exposure to dust on lung function of cement factory workers. Med J Malaysia 55(1):51–57

Oleru UG (1984) Pulmonary function and symptoms of Nigerian workers exposed to cement dust. Environ Res 33:379–385

Robins T, Seixas N, Franzblau A et al (1997) Acute respiratory effects on workers exposed to Metalworking fluid aerosol in an automotive transmission plant. Am J Ind Med 31:510–524

Thomson ML, Myers JE, Kriebel D (1998) Prevalence odds ratio or prevalence ratio in the analysis of cross sectional data: what is to be done? Occup Environ Med 55: 272–277

Ulvestad B, Bakke B, Eduard W, Kongerud J, Lund MB (2001) Cumulative exposure to dust causes accelerated decline in lung function in tunnel workers. Occup Environ Med 58:663–669

Vestbo J, Rasmussen FV (1990) Long-term exposure to cement dust and later hospitalisation due to respiratory disease. Int Arch Occup Environ Health 62(3):217–220

Wasserfallen JB, Gold K, Schulman KA, Baraniuk JN (1997) Development and validation of a rhinoconjuctivitis and asthma symptom score for use as an outcome measure in clinical trials. J Allergy Clin Immunol 100(1):16–22

Yang CY, Huang CC, Chiu HF, Chiu JF, Lan SJ, Ko YC (1996) Effects of occupational dust exposure on the respiratory health of Portland cement workers. J Toxicol Environ Health 49:581–588

Zock JP, Heederik D, Brunekreef B (1999) Influence of shift work and host factors on endotoxin-related acute peak flow changes. Am J Respir Crit Care Med 159:137–142