Dust exposure and impairment of lung function at a small iron foundry in a rapidly developing country

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Abstract

***Objectives*—A cross sectional prospective study was carried out among iron foundry workers (exposed) and soft drink bottling and supply company workers (unexposed) to assess their occupational exposure to ambient respiratory dust in their work environment and its effect on their lung function profile.**

***Participants*—Lung function was measured in 81 exposed and 113 unexposed workers. Personal respirable dust concentrations were measured for all the exposed and the unexposed workers. Information on respiratory signs and symptoms was also collected from the participants.**

***Results*—Among the exposed workers, midexpiratory flow (FEF_{25-75}), forced expiratory volume in 1 second (FEV_1), peak expiratory flow (PEF), FEV_1/FVC, and FEV_1/VC ratios were significantly lower whereas the vital capacity (VC) and forced vital capacity (FVC) were non-significantly higher. Job at the iron foundry was a significant predictor of lung function. Exposure to high concentration of respirable dust at the iron foundry was also a significant predictor. Workers working in high exposure areas (general works, furnace, continuous casting areas, and fabrication workshop) had lower lung function values than workers in medium and low exposure areas. Smoking did not enhance the effects of exposure to dust on lung function.**

***Conclusions*—Exposure to respirable dust was higher among the iron foundry workers; and among these, general, furnace, rolling mill, and fabrication workers had higher exposures to dust than did workers in continuous casting, the mechanical workshop, and the bottling plant. Job type and exposure to dust were significant predictors of lung function. Implementation of industrial hygiene and proper and efficient use of personal protection equipment while at work could help to protect the respiratory health of industrial workers.**

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Main messages

- Exposure to respirable dust at an iron foundry adversely affected lung function.
- Certain jobs at the iron foundry where exposure to respirable dust is high were affected to a greater extent than others.
- Respiratory signs and symptoms were also adversely affected in those exposed to respirable dust at iron foundry.
- Non-use of personal protective equipment resulted in greater exposure to dust.

Policy implications

- Workers at risk of exposure to respirable dust should be required to wear personal protection while at work.
- Personal protective equipment should be made available to the workers on the shop floor.

Occupational exposures to dust, fumes, and gases are associated with increased prevalences of respiratory symptoms and impairment of lung function.[1–4] Exposure-response relations between occupational agents and chronic respiratory symptoms have also been reported.[5 6] However, factors associated with lifestyle have also been identified as causing a deterioration of lung function. A strong relation between vital capacity (VC) and forced expiratory volume in 1 second (FEV_1) on the one hand and obesity on the other hand has been identified among Polish steel mill workers.[7 8] Other demographic variables have been shown to affect lung function, including age, weight, smoking, and socioeconomic conditions.[9 10]

Workers at steel manufacturing plants and iron foundries are exposed to a variety of agents including dusts from iron ore, coal, silica, and fumes and gases that comprise coke furnace emissions, metal fumes, iron oxides, and oxides of carbon, sulphur, and nitrogen. These workers, therefore, are at an increased risk of impaired lung function from chronic exposure to dust and fumes. A significant decline in lung function, consistent with slight airway obstruction, has been reported in steelworkers who worked in the continuous casting process.[11] Exposure to dusts in steel workers has also been strongly associated with reductions in forced vital capacity (FVC), FEV_1, and FEV_1/FVC%.[10] Significant decreases in FEV_1 and FVC have been associated with increases in occupational exposures to gases and fumes.[3] Combined occupational exposures to dusts and gases and fumes have been reported to reduce peak expiratory flow rate (PEF).[3]

Exposures at small cast iron foundries, where scrap iron is recycled to produce cast iron rods for use in construction, could be substantially higher than at huge steel manufacturing plants where efficient safety and hygiene practices are more likely to be enforced. This is liable to be true particularly in the newly industrialising countries—such as in the Arabian Gulf States. Further, the smaller foundries do not usually include dust precipitators and fume extractors—incorporated in the design and construction of the foundry—to provide a safe working environment for its workers, as was found in this study.

This study was designed to assess the effect of occupational exposures to dusts, fumes, and gases on the lung function of the workers at a cast iron foundry. A group of workers unexposed to similar dusts, gases, and fumes and working at a soft drink bottling plant was also studied for their lung function profile. Lung function and respiratory symptoms for the two groups of workers are described in this paper. The effects of exposure to dust and smoking on lung function have also been examined.

Methods

The exposed workers in the foundry and involved in the production process were invited to participate in the study; all were included as none refused to participate. Another group of workers at the soft drink bottling company, which was a bottling and supply factory, were included as the wholly unexposed group; again, none refused to participate. Only those workers on annual or other leave during the period of the study did not take part. The managements of the foundry and the bottling plant provided a list of workers, their job titles, and their ages along with the layout of different work units within the factory. Having arranged with the management of the factory, an appointment was made with the production supervisors to conduct the study on specified days during the study period. The supervisors requested those workers who had been off duty for at least the past 8 hours to report to the site laboratory before beginning their shift to participate in the study. At the site laboratory, the procedures to be applied were explained to these workers and their willingness to participate was confirmed by their signing the consent form. The ethics committee of the medical faculty had earlier given clearance for the procedures to be applied in this study including the questionnaire, and the work was conducted between September and December of 1997.

Lung function was assessed in groups of workers who had been employed for at least 3 years at the iron foundry and another group of workers at the soft drink bottling company. The mean values of the lung function profiles of the workers identified as exposed by job title at the foundry and performing similar tasks were compared with the mean values for other groups in the foundry who were less exposed and with the unexposed group as a whole. Qualitative and quantitative analyses of the respirable dust in the foundry premises affecting the workers as they performed the various tasks at the different work sites were undertaken and correlations with values of lung function were investigated. The workers at the foundry (the exposed group) were assigned to different work units within the foundry, although their tasks within the work units were rotated about every 2 years within the unit. At the soft drink factory, the workers (the unexposed group) attended to the automatic bottling tasks at the factory or were dispatched to supply the finished products to the retailers. As these tasks were switched between workers on a daily basis, no categorisation of tasks was done for these workers.

Information on sociodemographic characteristics, smoking profile, respiratory history, a general health profile, and current medication was collected through a questionnaire administered by an interviewer, modified from the American Thoracic Society standardised questionnaire. As all the workers were of Asian origin and some were unable to converse in English, the questionnaires were applied through an interviewer using their local language (Urdu). Before using the questionnaire in their local language the questionnaire was translated into Urdu and pilot tested and then back translated into English; the translations were tested through two back translations. Information was also collected about the use of personal protection while at work. Height, weight, and systolic and diastolic blood pressures were measured at the site laboratory. The body mass index (BMI) was calculated as a ratio of the weight in kilograms and the height in meters squared. Smoking profile (number of cigarettes a day and the smoking period) was used to calculate pack-years of smoking for current and ex-smokers. A pack-year is defined as smoking 20 cigarettes a day for a year. After the workers had completed the questionnaires, their lung function measurements were made. On the same day, environmental dust measurements were carried out for each of the workers, with a personal dust sampler.

Lung function was measured with a Vitalograph (Model PFII, Vitalograph, Buckingham, UK) spirometer according to the American Thoracic Society recommendations.[12] The spirometer was calibrated at the site laboratory as recommended by the manufacturer with a 1 litre calibration syringe, before use and after every 10 subjects. The procedure for the lung function test was explained individually to each of the subjects who were then given a practice test done while standing. If blowing into the spirometer was satisfactory, the actual test was done immediately. If the actual test was properly taken at the first attempt then three reproducible tracings were obtained, if not, the subject was asked to repeat the whole test. A record of the test was kept on a chart paper and the American Thoracic Society best results were printed. No subjects were excluded because of lack of reproducibility consistent with the American Thoracic Society guidelines.[13] The routine lung function profile included VC, FVC, FEV_1, forced mid-expiratory flow (FEF_{25-75}), PEF, and the per cent ratios for FEV_1/FVC and FEV_1/VC.

Impairment of lung function was classified according to the categories already described.[14 15]

Dust concentrations at different sites in the factory were measured with Casella personal sampling pumps AFC 123 (Cassella, London, UK). The pumps had previously been charged and calibrated at the site with a 5 µm pore size, 37 mm diameter, mixed cellulose ester filter paper (Millipore, Ireland). The personal sampling pumps, equipped with a cyclone filter head, were loaded with filter papers and were put on the workers during the shift; the respirable dust was sampled for 6 hours. At the end of this period, the pumps were removed and the filter papers were analysed quantitatively and then qualitatively for iron and manganese by flame atomic absorption spectrometry.[16] Dust concentrations were calculated for each of the workers and mean dust concentrations were also estimated for each job category including the unexposed jobs. A new categorical variable for dust concentration was computed with three categories: (1) low concentration (for those working at the bottling plant); (2) medium concentration (for those working in the mechanical workshop and continuous casting areas); and (3) high concentration (for those working in general works, furnace area, rolling mill area, and fabrication workshop).

Means (SDs) were used to describe continuous variables, and frequencies and percentages were used to describe categorical variables. Two independent sample *t* tests were used to compare the lung function variables between the exposed and the unexposed groups. χ^2 Analyses were used to test the associations between categorical variables (respiratory symptoms between the exposed and the unexposed groups). Multivariate regression analyses were conducted with the general linear model from the statistical package for social sciences (SPSS).[17] A multiple regression analysis technique was used to fit three different models. The first model assessed job type, the second exposure to dust with two dummy variables, and the third model job category with six dummy variables. The common potential predictors were age and pack-years.

The first regression model was computed with lung function measurements (VC, FVC, FEV_1, PEF, FEV_1/FVC, and FEV_1/VC) as dependent variables and job type (iron foundry or bottling plant workers), age, and pack-years as covariates; the intercept was also included in the model. Job type was coded as: exposed (iron foundry workers)=1 and unexposed (bottling plant workers)=0. The second multivariate regression model was computed with exposure to dust (actual dust measurements) as a covariate along with age, pack-years, and lung function measurements as dependent variables. Exposure to dust was coded as: (1) low (mean (SD) dust concentration 0.26 (0.07) mg/m^3); (2) medium (mean (SD) dust concentration 5.31 (1.49) mg/m^3); and (3) high (mean (SD) dust concentration 20.97 (1.46) mg/m^3). In this model two dummy variables (dust 1 and dust 2) were also included to adjust for the three concentrations of exposure to dust and low exposure was considered to be the reference category. The third and the final multivariate regression model was similar and contained job category (jobs classified according to the type of work done by the workers at the iron foundry and the bottling plant) along with age and pack-years as covariates and lung function measurements as dependent variables. Job categories were: (1) unexposed (bottling plant) workers; (2) mechanical workshop workers; (3) continuous casting workers; (4) general workers; (5) furnace workers; (6) rolling mill workers; and (7) fabrication workshop workers. Six dummy variables (job 1, job 2, job 3, job 4, job 5, and job 6) were created for job category to adjust for the seven job categories with job category 1 (bottling plant workers) as a reference category. All the models were tested for interactions between the covariates. The regression models were also tested without pack-years as a covariate to assess the contribution by smoking to the predictability of lung function by job type, exposure to dust, and job category (exposure to respirable dust).

Results

A total of 81 iron foundry workers (exposed) were examined in the study along with 113 soft drink company workers (unexposed). The salary and the living conditions of the exposed and the unexposed workers were similar, as was their socioeconomic status. Both the exposed and the unexposed workers generally stayed in a camp adjacent to the factory; only a small percentage (2%) of the unexposed workers stayed on their own outside the factory premises. Among the exposed group, 69% were of Indian origin and 31% of Pakistani and Bangladeshi origins; among the unexposed workers, 66% were of Indian origin and 36% of Pakistani, Bangladeshi, and Sri Lankan origin. The mean (SD) duration of service in the country in the job were 11.23 (5.2) years for the exposed and 11.69 (4.6) years for the unexposed populations. The differences in the mean BMI, systolic and diastolic blood pressures, and years of service between the exposed and the unexposed workers were not significant at $p<0.05$ (table 1). However, the unexposed population was significantly younger and slightly leaner compared with the exposed population. The unexposed population was also found to have smoked more (mean (SD) 0.34 (0.7) pack-years) than the exposed population (mean (SD) 0.30 (0.39) pack-years). Among the exposed workers the mean (SD) pack-years for the different job categories were: furnace workers 0.15 (0.52); continuous casting 0.18 (0.67); rolling mill 0.28 (0.58); mechanical workshop 0.53 (0.90); fabrication workshop 0.46 (0.94); general works 0.37 (0.68).

The numbers (%) of workers in the different work units which were identified and listed as job categories among the exposed workers were furnace workers 21 (26); continuous casting workers 13 (16); rolling mill workers 10 (12); mechanical workshop workers 10 (12); fabrication workers 12 (15); and general workers 15

Table 1 Age, BMI, systolic (SBP) and diastolic blood pressures (DBP), and years of service for exposed and unexposed workers according to the job category (mean (SD))

Job category	*Age (y)*	*BMI*	*SBP (mm Hg)*	*DBP (mm Hg)*	*Duration of stay in the camp (y)*	*Duration of service (y)*
Furnace (n=21)	43.1 (7.3)	25.1 (3.2)	123.3 (16.9)	78.3 (8.9)	11.14 (5.2)	11.52 (5.3)
Continuous casting (n=13)	38.8 (6.7)	25.9 (3.1)	132.7 (20.6)	85.8 (11.7)	14.08 (4.1)	14.38 (4.2)
Rolling mill (n=10)	39.4 (4.5)	25.1 (1.8)	123.5 (9.4)	77.5 (9.2)	9.4 (6.4)	9.40 (6.4)
Mechanical workshop (n=10)	41.0 (8.2)	23.9 (2.4)	126.5 (16.3)	80.0 (15.8)	8.9 (6.2)	8.90 (6.2)
Fabrication workshop (n=12)	42.2 (5.7)	25.9 (2.9)	130.4 (19.7)	81.6 (13.8)	10.67 (4.5)	10.67 (4.6)
General works (n=15)	40.0 (6.5)	26.3 (3.0)	128.3 (20.1)	80.0 (14.4)	12.13 (3.9)	12.13 (4.0)
Exposed (n=81)	40.9 (6.5)*	25.4 (2.9)	127.2 (17.8)	80.4 (12.3)	11.2 (5.1)	11.23 (5.2)*
Unexposed (n=113)	34.8 (8.8)*	24.6 (3.4)	126.4 (12.3)	80.2 (10.2)		11.69 (4.6)*

*p<0001, *t* test for independent samples.

(19) (table 1). The last category contained workers who could be mobilised to any unit on a daily basis, depending on the workload or to replace absentees. These workers also helped in different tasks related to the melting of the scrap and the casting of iron ingots and in the production unit. None of the workers used any protective equipment while at work except for shoes, which were worn by only 54% of the workers from the furnace, continuous casting, and rolling mill units, the rest of the workers wore bathroom slippers.

The frequencies of self reported recurrent and prolonged cough, phlegm, wheeze, and dyspnoea were significantly higher among the exposed than the unexposed workers (table 2). Among exposed workers the frequency of respiratory symptoms was significantly higher among mechanical workers (cough 30%, phlegm 30%, wheeze 20%, and dyspnoea 30%), furnace workers (cough 62%, phlegm 52%, and dyspnoea 24%) and the fabrication workers (cough 68%, phlegm 50%, wheeze 33%, and dyspnoea 42%). The lung function values for FEF_{25-75}, FEV_1, FEV_1/FVC, FEV_1/VC, and PEF were significantly lower for the exposed group than the unexposed group (table 2). The mean personal dust concentrations for different job categories are shown in table 3. The mean dust concentrations for the exposed workers (16.53 (7.25) mg/m^3) were significantly different from those of the unexposed workers (0.26 (0.07) mg/m^3) (table 3). The iron and manganese concentrations in these dust samples are also shown in table 3. The furnace, rolling mill, fabrication, and the general work groups were exposed to higher concentrations of respirable dust than the mean concentrations of ambient dust in the factory (table 3). Although the dust concentrations in the continuous casting area were lower, higher concentrations of iron and manganese found in this area may have resulted from the higher concentrations of fumes (not measured in this study); however, these values were lower than the American Conference of Governmental Industrial Hygienists (ACGIH) time weighted average (TWA) values (1987) of 5 mg/m^3 for manganese and 5 mg/m^3 for iron and iron oxides.

The results of the multivariate regression analyses of the first model indicated job type as a significant predictor of all lung function measurements (VC, FVC, PEF, FEV_1/FVC, and FEV_1/VC) except FEV_1 (table 4). Age but not pack-years contributed significantly to the model. There was no interaction between job type and age, or pack-years, or both. Having excluded pack-years from the regression model, job type, however, was still a significant predictor for all the lung function measurements except FEV_1. The second regression model indicated that exposure to dust was a significant predictor of all lung function measurements except FEV_1 (table 5). Age (VC, FVC, FEV_1, and FEV_1/VC) and pack-years (VC, FVC, and FEV_1) were significant contributors to the regression model. There was no significant interaction between exposure to dust and age, or pack-years, or both. Exposure to dust was still a significant predictor of lung function (VC, FVC, PEF, FEV1/FVC, FEV1/VC) after excluding pack-years from the regression model. In the third regression model job category (continuous casting workers, general workers) was a significant predictor of lung function (VC, FVC, PEF, and FEV_1/FVC, table 6). Lung function (FEV1, PEF, FEV_1/FVC, and FEV_1/VC) was also significantly predicted in workers with jobs as furnace workers or fabrication workers. Age (VC, FVC, and FEV_1) and pack-years (VC, FVC, and FEV_1) contributed significantly to the regression model. However, the interaction between job category and age or pack-years or both was significant only for VC but not for any of the other lung function values. Job category (continuous casting workers, general workers, furnace workers, and fabrication workers) was still a significant predictor for most of the lung function variables (VC, FVC, FEV_1, PEF, FEV1/FVC, and FEV_1/VC) after excluding pack-years from the regression model (table 6).

Discussion and conclusions

The workers at iron foundries are exposed to dust, fumes, and gases comprising silica, carbon, iron, and manganese.[10] Dusts, fumes, and manganese have been reported to have an adverse affect on the lung function of workers exposed to these agents.[10 15] In this study iron foundry workers were found to have been exposed to higher concentration of dust than soft drink bottling plant workers, and among these workers those in certain jobs were more exposed than others. Those workers (furnace and fabrication workers) exposed to high concentrations of dust and fumes were found to have higher frequency of respiratory symptoms (cough, phlegm, wheeze, and dyspnoea). These exposures may have affected adversely the lung function of the exposed workers, whose values

Table 2 Respiratory history (frequency) and lung function profile (mean (SD)) for exposed and the unexposed subjects

	Exposed (n=81)	Unexposed (n=113)	p Value
Cough (n (%))	31 (38.3)	9 (7.9)	0.0001*
Phlegm (n (%))	25 (30.9)	5 (4.4)	0.0001*
Wheeze (n (%))	9 (11.1)	5 (4.4)	0.06*
Dyspnoea (n (%))	17 (20.9)	7 (6.2)	0.003*
VC (l, mean (SD))	3.15(0.61)	3.00(0.55)	NS†
FVC (l, mean (SD))	3.20(0.59)	3.06(0.65)	NS†
FEF_{25-75} (l, mean (SD))	2.44(1.09)	3.80(1.13)	0.0001†
FEV_1 (l/s, mean (SD))	2.42(0.74)	2.68(0.53)	0.005†
FEV_1/FVC (%, mean (SD))	75.80(17.75)	88.47(9.89)	0.0001†
FEV_1/VC (%, mean (SD))	77.11(18.78)	89.82(10.82)	0.0001†
PEF (l, mean (SD))	276.36(145.41)	426.01(120.51)	0.0001†

NS=Not significant.
*χ^2 test.
†*t* Test for independent samples.

Table 3 Respirable dust exposures among the different job categories (mean (SD))

Job categories	*Respirable dust (mg/m³)*	*Iron in respirable dust (μg/m³)*	*Manganese in respirable dust (μg/m³)*
Furnace	20.47(1.14)	254.70(120.13)	10.89(12.95)
Continuous casting	6.58(0.19)	703.22(81.41)	28.63(0.51)
Rolling mill	21.82(1.71)	251.24(129.93)	10.27(10.97)
Mechanical workshop	3.66(0.29)	242.25(160.67)	9.67(7.84)
Fabrication workshop	21.89(1.38)	342.34(115.04)	19.44(10.06)
General works	20.37(1.19)	243.62(123.16)	10.52(12.73)
Exposed workers	16.53(7.25)*	339.56(182.17)	14.90(7.66)
Unexposed workers	0.26(0.07)*	ND	ND

ND=Not detected.
*p<0.0001, analysis of variance (ANOVA).

for FEF_{25-75}, FEV_1, FEV_1/FVC, FEV_1/VC, and PEF were lower than the values among comparison workers at the soft drink bottling plant where there was no occupational exposure to such air pollutants. The slightly higher values noted for VC and FVC in the exposed workers than the unexposed workers may have been due to the healthy worker effect and to the hard manual labour required from the exposed workers. Similar effects of manual work on lung function, irrespective of the exposures, have been reported by Sobaszek *et al*[18] and Knudson *et al*[19] among stainless steel workers and have been ascribed to the healthy worker effect. The intensity of the manual activity among the exposed and unexposed workers was not measured in this study; however, the occupational hygienist on the research team found it to be higher for the exposed workers than for the unexposed workers. The prevalence of chronic cough, phlegm, wheeze, and dsypnoea was higher among the exposed workers than the unexposed workers; these findings are in agreement with other similar studies.[20 21]

In this study the type of job (iron foundry or bottling plant worker) and also occupational exposure to dust significantly predicted lung function (VC, FVC, FEV_1/FVC, and PEF) indicating that occupational exposure to respirable dust in an iron foundry played a significant part in decreasing lung function of the exposed workers and in increasing the risk of chronic airflow limitations. Similar effects have been found among brick manufacturing workers and among workers exposed to silica.[22 23] An inverse relation was found for exposure to dust and FEV_1, PEF, FEV_1/FVC, and FEV_1/VC. The inclusion or exclusion of pack-years, a measure of smoking profile, in the regression model did not significantly alter the ability of job type and exposure to dust to predict lung function. Therefore, the deleterious effects of smoking were not found as anticipated, among the exposed and the unexposed workers. Although all the lung function variables were lower among the exposed smokers than the exposed non-smokers, similar effects were not found among unexposed smokers and non-smokers. Thus, although smoking is usually reported to impair lung function, in this study smoking was not found to further exacerbate lung function in workers who were exposed to high dust concentrations. This may possibly be because of the low intensity of smoking among the exposed and the unexposed groups, and secondly in estimating pack-years we did not differentiate between current smokers and ex-smokers.

The respirable dust concentrations varied widely between the different work areas, depending on the nature of the work carried out at the unit. The variations in the dust concentrations were partly the result of the differences in the generation of the dust at the various worksites and partly the rapidity with which natural ventilation removed the spill of dust from the worksites as the high ambient temperatures during most of the year dictated

Table 4 Multivariate regression analysis to examine job type, age, and smoking as a predictors of lung function

	Dependent variables								
	VC			*FVC*			*FEV_1*		
Covariates	*β*	*SE*	*p Value*	*β*	*SE*	*p Value*	*β*	*SE*	*p Value*
Intercept	3.552	0.235	0.000	3.795	0.262	0.000	3.465	0.256	0.000
Job type	0.280	0.084	0.000	0.273	0.094	0.004	−0.107	0.091	0.245
Age	−0.014	0.006	0.026	−0.019	0.007	0.007	−0.022	0.007	0.002
Pack-years	0.475	0.460	0.303	0.120	0.511	0.814	0.359	0.500	0.473
Intercept	3.812	0.192	0.000	3.932	0.210	0.000	3.643	0.202	0.000
Job type	0.300	0.087	0.001	0.296	0.095	0.002	−0.096	0.091	0.294
Age	−0.023	0.005	0.000	−0.025	0.006	0.000	−0.027	0.006	0.000
	PEF			*FEV_1/FVC*			*FEV_1/VC*		
Intercept	437.5	57.72	0.000	93.45	6.006	0.000	99.843	6.408	0.000
Job type	−137.8	20.64	0.000	−11.43	2.149	0.000	−11.203	2.293	0.000
Age	−0.337	1.55	0.828	−0.159	0.161	0.324	−0.301	0.172	0.081
Pack-years	146.6	112.8	0.195	7.275	11.735	0.536	−1.904	12.52	0.879
Intercept	493.18	45.53	0.000	95.51	4.690	0.000	98.522	5.021	0.000
Job type	−137.8	20.58	0.000	−11.61	2.118	0.000	−11.35	2.272	0.000
Age	−1.930	1.259	0.127	−0.202	0.130	0.121	−0.250	0.139	0.073

Job type: 1=iron foundry; 0=bottling plant.

the clearance of external walls and the minimum of internal partitions. Thus, the dust concentrations were higher at the furnace, rolling mill, fabrication, and general work areas where the bulk of the pollutants were generated. The workers in these areas had lower lung function values than their colleagues in the bottling plant as shown by regression analysis. Working in areas of high exposure to dust (furnace, fabrication, and general works) was a significant risk factor for lower measurements of lung function. These workers (furnace and fabrication) were also found to show an increased frequency of respiratory signs and symptoms. Working in the continuous casting area was a significant predictor of lung function

Table 5 Multivariate regression analysis to examine dust exposure, age, and smoking as a predictors of lung function

	Dependent								
	VC			*FVC*			*FEV_1*		
Covariates	*β*	*SE*	*p Value*	*β*	*SE*	*p Value*	*β*	*SE*	*p Value*
Intercept	3.767	0.184	0.000	3.902	0.206	0.000	3.635	0.202	0.000
Dust 1 (dummy)	0.458	0.124	0.000	0.352	0.138	0.012	−0.141	0.135	0.300
Dust 2 (dummy)	0.187	0.092	0.044	0.231	0.103	0.027	−0.103	0.101	0.310
Age	−0.019	0.005	0.000	−0.022	0.006	0.000	−0.025	0.006	0.000
Pack-years	−0.276	0.072	0.000	−0.250	0.080	0.002	0.157	0.079	0.047
Intercept	3.789	0.191	0.000	3.922	0.210	0.000	3.648	0.203	0.000
Dust 1 (dummy)	0.478	0.128	0.000	0.370	0.141	0.009	−0.129	0.136	0.344
Dust 2 (dummy)	0.223	0.095	0.020	0.264	0.105	0.013	−0.082	0.101	0.419
Age	−0.023	0.005	0.000	−0.025	0.006	0.000	−0.028	0.006	0.000
	PEF			*FEV_1/FVC*			*FEV_1/VC*		
Intercept	492.7	45.69	0.000	95.95	4.71	0.000	99.42	4.97	0.000
Dust 1 (dummy)	−148.9	30.66	0.000	−14.47	3.16	0.000	−16.97	3.34	0.000
Dust 2 (dummy)	−136.5	22.90	0.000	−10.25	2.36	0.000	−8.63	2.49	0.001
Age	−1.700	1.28	0.186	−0.223	0.13	0.094	−0.295	0.14	0.036
Pack-years	−21.79	17.86	0.224	0.781	1.84	0.672	1.963	1.94	0.314
Intercept	494.43	45.72	0.000	95.89	4.69	0.000	99.26	4.97	0.000
Dust 1 (dummy)	−147.4	30.67	0.000	−14.5	3.15	0.000	−17.12	3.33	0.000
Dust 2 (dummy)	−133.6	22.81	0.000	−10.4	2.34	0.000	−8.89	2.48	0.000
Age	−1.966	1.256	0.122	−0.213	0.13	0.103	−0.271	0.137	0.050

Dust exposure (1=low exposure, 2=mild exposure, 3=high exposure).
Low dust exposure is reference group; dust1 (dummy)=mild exposure; dust2 (dummy)=high exposure.

Table 6 Multivariate regression analysis to examine job categories, age and smoking as a predictors of lung function

	Dependent								
	VC			*FVC*			*FEV_1*		
Covariates	*β*	*SE*	*p Value*	*β*	*SE*	*p Value*	*β*	*SE*	*p Value*
Intercept	3.703	0.182	0.000	3.841	0.203	0.000	3.563	0.197	0.000
Job 1 (dummy)	0.362	0.174	0.039	0.145	0.194	0.456	−0.023	0.188	0.903
Job 2 (dummy)	0.515	0.154	0.001	0.497	0.172	0.004	−0.252	0.167	0.133
Job 3 (dummy)	0.508	0.145	0.001	0.567	0.162	0.001	0.219	0.157	0.165
Job 4 (dummy)	0.028	0.131	0.831	0.136	0.147	0.360	−0.367	0.143	0.011
Job 5 (dummy)	0.319	0.172	0.066	0.288	0.193	0.137	0.212	0.187	0.282
Job 6 (dummy)	−0.11	0.161	0.513	−0.121	0.180	0.505	−0.376	0.175	0.033
Age	−0.017	0.005	0.001	−0.020	0.006	0.001	−0.024	0.006	0.000
Pack-years	−0.279	0.071	0.000	−0.241	0.080	0.003	−0.181	0.078	0.021
Intercept	3.726	0.188	0.000	3.862	0.207	0.000	3.579	0.199	0.000
Job 1 (dummy)	0.333	0.180	0.066	0.120	0.198	0.545	−0.042	0.190	0.827
Job 2 (dummy)	0.574	0.159	0.000	0.548	0.174	0.002	−0.214	0.168	0.204
Job 3 (dummy)	0.519	0.150	0.001	0.576	0.165	0.001	0.226	0.159	0.156
Job 4 (dummy)	0.110	0.135	0.417	0.205	0.148	0.168	−0.314	0.142	0.029
Job 5 (dummy)	0.354	0.179	0.049	0.318	0.197	0.107	0.225	0.189	0.236
Job6 (dummy)	−0.112	0.167	0.505	−0.126	0.184	0.495	−0.380	0.177	0.033
Age	−0.021	0.005	0.000	−0.023	0.006	0.000	−0.026	0.006	0.000
	PEF			*FEV_1/FVC*			*FEV_1/VC*		
Intercept	482.9	45.85	0.000	95.13	4.64	0.000	98.66	4.99	0.000
Job 1 (dummy)	−155.3	43.85	0.001	−7.37	4.44	0.098	−12.69	4.70	0.008
Job 2 (dummy)	−146.6	38.77	0.000	−20.24	3.92	0.000	−20.51	4.21	0.000
Job 3 (dummy)	−129.5	36.51	0.000	−8.35	3.69	0.025	−6.47	3.97	0.105
Job 4 (dummy)	−160.9	33.18	0.000	−15.75	3.36	0.000	−12.60	3.61	0.001
Job 5 (dummy)	−58.92	43.55	0.178	−2.20	4.41	0.618	−2.52	4.74	0.595
Job 6 (dummy)	−176.4	40.75	0.000	−10.93	4.12	0.009	−10.44	4.43	0.020
Age	−1.419	1.288	0.272	−0.191	0.130	0.144	−0.268	0.14	0.057
Pack-years	−21.91	18.04	0.226	−0.017	1.826	0.993	1.460	1.96	0.458
Intercept	484.8	45.88	0.000	95.13	4.62	0.000	98.53	4.98	0.000
Job 1 (dummy)	−157.5	43.87	0.000	−7.37	4.42	0.097	−12.55	4.76	0.009
Job 2 (dummy)	−142.0	38.64	0.000	−20.23	3.89	0.000	−20.81	4.19	0.000
Job 3 (dummy)	−128.6	36.54	0.001	−8.34	3.68	0.025	−6.53	3.97	0.101
Job 4 (dummy)	−154.6	32.79	0.000	−15.74	3.31	0.000	−13.03	3.56	0.000
Job 5 (dummy)	−56.14	43.55	0.199	−2.20	4.39	0.617	−2.71	4.72	0.568
Job6 (dummy)	−176.8	40.79	0.000	−10.93	4.11	0.009	−10.41	4.43	0.020
Age	−1.690	1.270	0.185	−0.191	0.12	0.137	−0.250	0.13	0.071

Job category: 1=bottling plant workers; 2=mechanical workshop workers; 3=continuous casting workers; 4=general workers; 5=furnace workers; 6=rolling mill workers; 7=fabrication workshop workers.
Job category=1 is reference category, Job1 (dummy)=mechanical workshop workers, Job2 (dummy)=continuous casting workers, Job3 (dummy)=general workers, Job4 (dummy)=furnace workers, Job5 (dummy)=rolling mill workers and Job6 (dummy)=fabrication workers.

despite low dust concentrations, possibly because of high exposure to fumes and gases. Lung function in rolling mill workers did not reflect higher exposure to dust in that area, possibly because workers did not work in such a confined space as in other areas because of the nature of the work. They could monitor the production of cast iron from a safe distance. Smoking, although an independent factor which adversely affects lung function, in this study did not contribute additionally to the already lowered lung function resulting from exposure to dust. The non-use of personal protection equipment, resulting in increased exposure, might have contributed to the excess decrements found among the high exposure groups. The workers in those areas with high dust concentrations were also found to be involved in greater physical activity than workers in other areas, thereby increasing their exposure.

In conclusion, therefore, the workers at the iron foundry were found to have a lower lung function than workers in those areas with lower dust concentrations. These workers were also at an increased risk of developing chronic respiratory airflow limitations than their counterparts in a non-polluted environment. The higher frequencies of cough, phlegm, wheeze, and dyspnoea among the exposed group, with highest values among the furnace and fabrication workers, show a possible dose-response relation. These workers do not consider these symptoms of ill health for they have accepted these illnesses as part of the job risk. Being economic migrants from the Indian subcontinent, all the study subjects needed to keep their jobs and to maintain their lifestyle, which is better than the one in their country of origin. The degree of lung impairment was higher among those workers exposed to higher concentrations of dust and gases and could eventually be a hindrance to their social life and wellbeing. The non-use of respiratory protective equipment while at work increased the exposure and consequently heightened the risk of lung impairment and chronic airflow limitations.

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