Industrial Health 2007, **45**, 409–414 **Original Article**

Occupational Exposure to Lignite and Impact on Respiratory System among Heavy Industry Personnel

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Received April 18, 2006 and accepted January 9, 2007

Abstract: Objective is to evaluate the impact of occupational exposure to lignite dust on respiratory system. 103 blue-collar workers exposed to lignite dust and 62 controls completed a questionnaire on respiratory symptoms and underwent spirometry. Levels of lignite dust in workplace were measured. Univariate and multivariate analysis of the data were performed. The concentration of lignite dust varied from 0.6 to 1.4 mg/m^3. Current smokers and workers exposed to lignite dust presented higher prevalence of chronic bronchitis symptoms and of FEV<80% and FEV1/FVC<70%. Multivariate analysis has shown that smoking and occupational exposure to lignite dust were independent predictors of chronic bronchitis symptoms, as well as of an obstructive ventilation pattern. Further analysis showed that exposed workers who were current smokers presented a five fold rate for developing an obstructive ventilation pattern in comparison to exposed workers non currently smokers. Occupational exposure to lignite dust and smoking were independent determinants of chronic bronchitis symptoms and obstructive ventilation pattern. There is some evidence for a combined effect of smoking and lignite dust exposure on respiratory system.

Key words: Lignite, Worker, Smoking, Dust, Respiratory system

Introduction

Chronic obstructive pulmonary disease (COPD) has significant occupational and socio-economic determinants. ‘Low social position’ has been associated with an increased risk for chronic bronchitis/emphysema[1]. Furthermore, there is strong evidence that exposure to coal dust among miners is associated with an increased risk for chronic bronchitis, and emphysema[2] However the confounding effect of smoking, which is the most important factor in the development of COPD, and the multi-factorial etiology of COPD complicate further the study of its occupational determinants[3].

Lignite is a fossil, which contains carbon, and other elements. It’s largely dispersed in some areas of Greece[4]. Lignite combustion is used for the production of electric energy, and more than 75% of the electric power amount produced in Greece is generated by seven lignite combustion power stations[5]. The lignite is pulverized and consequently undergoes combustion process in boilers. In this process, dust and gas produced are drawn off to precipitators and a separation process occurs. Gas is vented to the environment through chimneys, and the dust remains to the precipitators.

Very few studies investigated the impact of occupational exposure to lignite dust on the respiratory system.

A retrospective cohort study from Australia[6] has shown

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that age, smoking, and exposures to brown coal dust (lignite) were significant predictors of longitudinal decline in Forced Expiratory Volume in one second (FEV1). A Greek study[7], demonstrated that workers in surface lignite mines have reported significantly high percentage of chronic bronchitis symptoms while no significant changes in lung function tests were observed during the follow up period.

A recent Turkish cross- sectional study[8] among lignite miners has found that the prevalence of pneumoconiosis was 13.5%.

However, almost all the published information is based on data from lignite miners. To the best of our knowledge, there are no studies, regarding the effect of lignite on respiratory system, among workers at lignite combustion electrical power stations.

Our study is aiming to investigate the possible impact of lignite dust on the respiratory system of employees working in a lignite combustion electrical power unit.

Materials and Methods

Subjects

All 103 blue-collar workers at the pulverization area, and maintenance tasks of a lignite combustion electro-production unit (including operators, cleaners and boiler cleaners) comprised the study population, while the control group included all 62 workers at an oil combustion electro-production unit. The mean age of the workers (exposed group: 37.2, SD=5.7; non exposed group: 36.9, SD=7.8 was 37.17 yr (SD=6.6, range: 22–55 yr). The mean duration of employment (exposed group: 10.6 yr, SD=4.9; non exposed group: 9.1, SD=7.6) was 10.3 yr (SD=5.03, range: 1–22 yr).

Environmental monitoring

The assessment of the environmental exposure to lignite dust (respirable fraction) for the study group was performed by the use of the gravimetric method. In particular, air was drawing through a cellulose filter of known weight that was adapted in a personal sampler device that was attached to a sampling pump of fixed flow (MSA Company, Pittsburgh, Pennsylvania, USA). Reweighing of the filter, after sampling, gives a measurement of the dust weight, and thus of dust concentration at workplace. Respirable fraction of dust was also measured for control group using the above methodology.

Assessment of chronic bronchitis symptoms

Prior to spirometry, all workers included in this study completed a self- administered questionnaire on chronic bronchitis symptoms based on the British Medical Research Council's Questionnaire[9]. In addition, employees completed a questionnaire regarding socio-demographic information (age, duration of employment, occupation, smoking habit). Regarding smoking habit, subjects were divided to current smokers, and non-current smokers. The subjects, who reported cigarette-smoking habit at the time of survey, were defined as current smokers. The subjects, who did not describe any smoking habit at the time of survey and at least for 3 months before, were, defined as non-current smokers.

Spirometry

Basic spirometry was performed to all subjects by using a portable spirometer (Vitalograph, Buckingham, England). Three technically satisfactory maximal forced exhalations were recorded and the best forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and the ratio FEV1/FVC were taken into account for statistical analysis. Predictive values of the above parameters were extracted based on the recommendations of the European Coal and Steel Community[10]. The evaluation of extracted values regarding the parameters of spirometry was based on GOLD criteria[11]. The spirometer was calibrated with a three-liter syringe.

Statistical analysis

Continuous variables are presented as mean (standard deviation) and categorical variables as absolute and relative frequencies. Associations between categorical variables were explored by the use of *chi*- square test (univariate analysis). Continuous variables were tested for normal distribution by Kolmogorov-Smirnov test. Univariate analysis of normally distributed continuous variables was performed by student's *t*- test. Logistic regression analysis was used as the multivariate analysis in order to assess the impact on symptomatic status, and respiratory function of occupational exposure to lignite dust, smoking habit, and age. In these models of multivariate analysis symptoms of chronic bronchitis and the ratio FEV1/FVC<70%, were the dependent variable, while age, smoking, and occupational exposure status, were the independent ones. Odds ratios (OR) and 95% confidence interval (95% CI) were calculated. The level of statistical significance was set at 0.05. Statistical analysis was performed by the use of SPSS software.

Results

The concentration of respirable fraction of lignite dust

Table 1. Distribution of spirometric mean values in relation to workers' socio-demographic features (n=165)

	Spirometric Values					
	FEV1/FVC (% predicted)		FEV1 (% predicted)		FVC (% predicted)	
Socio-demographic features	Mean	SD	Mean	SD	Mean	SD
Smoking						
Current smokers	90.2**	13.9	92.9*	16.7	99.0	12.8
Non current smokers	100.4	10.4	98.3	12.8	101.0	12.3
Occupational status						
Exposed to lignite	93.4	15.7	94.3	15.4	100.4	11.0
Non exposed to lignite	95.0	9.2	95.8	15.8	99.4	15.0
Age						
≤37 yr	95.0	13.3	95.0	15.0	101.2	11.7
>37 yr	93.0	14.0	94.0	16.0	98.8	13.4
Duration of employment						
≤10 yr	94.5	15.0	95.4	14.5	100.3	12.3
>10 yr	93.8	13.2	93.4	18.2	99.2	13.4

*$p<0.05$, **$p<0.001$.

for workers at pulverization area, and maintenance tasks varied from 0.6 to 1.4 mg/m^3 (TLV-TWA:0.9 mg/m^3). Workers of other departments at the lignite power station, and workers at the oil-combustion power station have presented a respirable fraction of dust between 0.01–0.02 mg/m^3. The prevalence of smoking was 67.3%. The analysis of questionnaire data has shown that workers who are currently smokers, exposed to lignite dust have recorded increased prevalence of chronic bronchitis symptoms. In particular, 34% of smokers reported symptoms of chronic bronchitis, while only 13% of non-smokers did so (*chi* square test, p=0.003). Regarding occupational status 35% of workers exposed to lignite dust reported chronic bronchitis symptoms in comparison with 13% of their non-exposed colleagues (*chi* square test, p= 0.002). Table 1 presents the mean values (SD) of FEV1, FVC, FEV1/FVC and their univariate analysis in subgroups of our study sample.

Current-smokers have recorded significantly lower levels of FEV1 in comparison with non-current smokers. In addition, current smokers had significantly lower levels of FEV1/ FVC ratio in comparison to non-current smokers.

Workers exposed to lignite dust presented insignificantly lower levels of FEV1 and FEV1/ FVC ratio. Univariate analysis did not show a significant association of mean values of both FEV1 and FEV1/ FVC ratio with age and duration of exposure.

Table 2 presents the univariate analysis of FEV1 <80% and FEV1/FVC <70% in subgroups of our study sample. The prevalence of FEV1 <80% was significantly higher among current smokers in comparison to non current smokers. Furthermore, the homogeneous group of lignite exposed workers recorded significantly higher prevalence of FEV1 <80% in comparison with the homogeneous group of non-exposed workers. Univariate analysis did not show a significant association of the prevalence of FEV1 <80% with age and duration of employment. Table 2 also illustrates the univariate analysis of the prevalence of FEV1/ FVC <70%. Smokers recorded significantly higher prevalence of FEV1/ FVC <70% in comparison with non-smokers.

Table 2. Prevalence of FEV1<80% and FEV1/FVC<70% in relation to socio-demographic features of heavy industry personnel (n=165)

	Prevalence			
	FEV1 (% predicted)		FEV/FVC (% predicted)	
Socio-demographic features	<80	≥80	<70	≥70
Smoking				
Current smokers	28.6%*	71.4%	27.6%**	72.4%
Non current smokers	10.0%	90.0%	5.0%	95.0%
Occupational status				
Exposed to lignite	27.2%*	72.8%	25.2%**	74.8%
Non exposed to lignite	12.9%	87.1%	9.7%	90.3%
Age				
≤37 yr	18.8%	81.2%	20.0%	80.0%
>37 yr	25.0%	75.0%	18.7%	81.3%
Duration of employment				
≤10 yr	19.0%	81.0%	18.2%	81.8%
>10 yr	29.5%	70.5%	22.7%	77.3%

*$p<0.05$, **$p<0.001$.

Employees exposed to lignite dust recorded significantly higher prevalence of FEV1/FVC <70% than their non-exposed colleagues. Age and duration of employment were not significantly associated with the prevalence of FEV1/FVC <70%.

Table 3 shows the results of logistic regression analysis of FEV1/FVC <70% with age, duration of employment, smoking, and occupational exposure status. Smoking and occupational exposure to lignite dust were independently associated with FEV/FVC <70%. In particular, current smokers have recorded a seven-fold (OR: 7.2; 95% Confidence Interval: 2.06–25.2) rate for developing FEV1/FVC <75% in comparison with non-current smokers. Workers exposed to lignite dust have presented a three-fold (OR: 3.07; 95% Confidence Interval: 1.15–8.22) rate for having un abnormal FEV1/FVC in comparison with those without exposure.

Furthermore, logistic regression analysis within the homogeneous group of employees exposed to lignite dust (n=103), revealed that exposed employees who were current smokers (n=68) recorded a five fold (OR: 5.4; 95% Confidence Interval: 1.49–19.6) rate for having FEV1/ FVC <70% in comparison to exposed workers who were not current smokers (reference category; n=35), after adjustment for age and duration of employment.

Logistic regression (dependent variable: symptoms of chronic bronchitis) documented that smoking (OR: 3.47; 95% CI: 1.45–8.33) and occupational exposures to lignite dust (OR: 3.48; 95% CI: 1.46–8.2) were independent predictors of the occurrence of chronic bronchitis symptoms, after adjustment for age and duration of employment.

Table 3. Multivariate analysis of FEV1/FVC and socio-demographic features (n=165)

	FEV1/FVC <70%		
	OR	95% CI	*p*
Socio-demographic features			
Smoking			
Current smokers	7.20	2.06–25.20	0.002
Non current smokers	1.00 (ref)		
Occupational status			
Exposed to lignite	3.07	1.15–8.22	0.01
Non exposed to lignite	1.00 (ref)		
Age			
≤37 yr	1.28	0.46–3.58	NS
>37 yr	1.00 (ref)		
Duration of employment			
≤10 yr	1.55	0.50–4.76	NS
>10 yr	1.00 (ref)		

NS: non significant.

Discussion

At first, our results have shown a high prevalence of smoking (67%) among the employees under study. This finding correlates well with previous studies among heavy industry workers in Greece[12, 13].

The results of the present cross- sectional study have demonstrated that smoking and occupational exposure to lignite dust were independently associated with the occurrence of bronchitis symptoms and of an obstructive pattern of ventilation. Regarding symptoms this finding is in line with previous studies. Rawling in an Australian cross sectional study among lignite workers found a significant increase in symptoms of cough, phlegm, and wheeze among workers with high levels of dust exposure[14]. Sichletidis and colleagues in a Greek longitudinal study found that workers in surface lignite miners who were living in the valley near by the mines reported an increased percentage of chronic bronchitis symptoms[7]. Our results indicate that workers currently smokers and occupationally exposed to lignite dust have reported a notable high prevalence of respiratory symptoms. The presence of respiratory symptoms could represent an early biological response to smoking and occupational exposures; thus, it could be a risk factor for loss of pulmonary function in the future[15]. Logistic regression analysis confirmed that occupational exposure to dust was an independent predictor of the occurrence of respiratory symptoms. Regarding lung function tests the results have shown a higher prevalence of FEV1 <80 and FEV1/FVC <70% among smokers and workers exposed to lignite dust. Multivariate analysis have documented that smoking and occupational exposure to lignite dust were independent predictors for the presence of FEV1/FVC <70%. In particular, smoking was the strongest predictor of FEV1/FVC <70% (OR: 7.2) followed by occupational exposure to lignite dust (OR: 3.07) after adjustment for age and duration of employment. Finocchiaro *et al.* in a previously mentioned Australian longitudinal study found that smoking and occupational exposure to lignite dust were significantly associated with a decline in lung function[6]. However, the effect of smoking was stronger than that of dust exposure. It has been suggested that the effect of occupational exposures on lung function is proportionally smaller to that of smoking[16]. Apart of that, the interaction between smoking and occupational exposures complicates further the evaluation of their combined effect on lung physiology. In this study multivariate analysis among workers exposed to lignite dust indicated that smokers had a five-fold rate of developing an obstructive ventilation pattern when compared with non-smokers. This finding implies a possible interaction between smoking and occupational exposure to lignite dust regarding the impact on lung function. A significant interaction between smoking and coal dust- their combined effect appear to be additive- has been reported in terms of loss of pulmonary function[17]. These data could form the base for the development of workplace based antismoking policies. It has been suggested that an effective antismoking policy in worksite should not be isolated but integrated into a broader context of occupational health and safety and health promotion. There is some evidence that offering programs to reduce exposures to occupational hazards may stimulate worker's participation in health promotion activities[18]. Employees and in particular, blue collar workers, do not compartmentalise their participation in health promotion and health protection programs, therefore, integrated health promotion / health protection initiatives are warranted. Such a holistic approach could significantly reduce both occupational exposures and smoking rate.

Our study has some limitations. As a cross sectional study provides evidence about possible association and not for causation. In addition, our sample was not entirely representative of the worker's population at lignite fire power plants. Therefore, the results cannot be generalized to the whole workforce of these plants. Another possible limitation is that we cannot exclude a residual confounding effect on the results by smoking even after multivariate analysis performed. The most notable limitation is that we were unable to provide the full spectrum of workers exposure at the power station. It generally seems that there are some other gaseous and particulate pollutants, such as sulphur oxides, nitrogen oxides or metal fumes, associated with the production of lignite. Thus, we can't exclude the possibility of a confounding effect both on respiratory symptoms, and lung function.

In conclusion, smoking and occupational exposure to lignite dust were associated with chronic bronchitis symptoms and airflow obstruction among electro-production workers. Although the effect of smoking on respiratory system was stronger than that of occupational exposure to lignite dust there was some evidence about their combined effect on respiratory system.

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