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Respiratory function in power plant workers exposed to nitrogen dioxide

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Background	Power plant workers are potentially exposed to nitrogen dioxide (NO_2) and may therefore be at higher risk of pulmonary diseases than the general population.
Aims	To assess the association of NO_2 exposure with spirometric abnormalities in power plant workers.
Methods	Forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and forced expiratory ratio (FER = FEV_1/FVC) were correlated with demographic characteristics, smoking history and environmental exposure to NO_2 in power plant workers exposed to environmental NO_2 at work and in a control group of administrative employees. Twenty-four hour environmental NO_2 concentrations were measured at each workplace.
Results	The concentrations of environmental NO_2 ranged from 1.21 to 7.82 mg m^{-3} with a mean value of 3.91 + 1.51 mg m^{-3}. The results showed that FEV_1 and FVC were significantly lower in 347 power plant workers than in the 349 controls ($P < 0.001$). The FER was significantly correlated with age, environmental NO_2 concentration, smoking and height.
Conclusions	Occupational exposure to NO_2 emissions in power plants is significantly associated with lung function abnormalities as assessed by spirometry. Spirometric measurements in power plant workers exposed to NO_2 emissions may be an effective means of detecting early signs of impaired respiratory health in this group of workers.

Key words FER; FEV_1; FVC; nitrogen dioxide; power generation; power plant; respiratory function; spirometry.

Introduction

Impairment of pulmonary function is a sensitive marker of respiratory health [1]. Historically, spirometry has been used to measure impairment of pulmonary function [2]. In obstructive airway disease, characteristic changes in spirometric parameters include a reduction in the forced expiratory volume in 1 s (FEV_1), with respect to the forced vital capacity (FVC) [1,2]. Fuel combustion for electricity generation in thermal power plants produces a complex mixture of pollutants, even with pollution control devices, including nitrogen oxides (NOx), acid gases, organic compounds and solid wastes such as fly ash and flue gas desulphurization materials [3–5]. Nitrogen dioxide (NO_2) is the main pollutant. Exposure to NOx has been associated with increased incidence of asthma exacerbation, respiratory-related hospitalizations, susceptibility to respiratory infection and mortality [4,6]. Power plant workers are occupationally exposed to NO_2 and may therefore be at higher risk of pulmonary diseases than the general population. To the best of our knowledge, there are no previous studies relating NO_2 exposure to lung function in power plant workers. The objective of this study was to assess the association of NO_2 exposure with respiratory function in workers from a major power plant in southern Italy.

Methods

The study was conducted on employed men at three oil-fired power plants in southern Italy between March and October 2013. They underwent a medical examination for routine health surveillance in accordance with the Italian Law on Health and Safety for Workers (Act 81/08) [7]. The study group consisted of workers (electricians, maintenance technicians, fitters and repairers) occupationally exposed to environmental NO_2 and

a control group of administrative employees. Every worker gave informed consent to the study and dissemination of personal data was anonymized. Participants were asked about potential confounding variables for environmental exposure to NO_2 and about lifestyle, particularly smoking habits. All participants provided spirometric measurements, using a computerized spirometer calibrated daily with a 3 l syringe. A forced expiratory ratio (FER = FEV_1/FVC) of <70% was used as the criterion for airflow obstruction. A purely restrictive pattern was defined as having an FVC <80% of predicted and an FER ≥70%. The best of three tests was recorded. Spirometric measurements complied with the American Thoracic Society acceptability and reproducibility criteria [8]. Environmental NO_2 concentrations were measured continuously during the daily activity of the power plants at each workplace using a specific analyzer. The average exposure value for each work location was subsequently associated with workers in that area. Statistical analyses were conducted with SPSS, version 14.01 for Windows (SPSS Inc., Chicago, IL, USA). The spirometric measurements were correlated with background demographic characteristics, environmental exposure to NO_2 and smoking history first by univariate analysis (two-sample *t*-test for continuous data, and χ^2-test for categorical variables) and then by multiple linear regression analyses. Multiple colinearity was considered and the model building strategy suggested by Hosmer and Lemeshow [9] was applied (excluded before entering of variables into multiple regression analysis). A *P* value of <0.05 was considered statistically significant.

Results

A total of 696 employed men (347 power plant workers and 349 controls) participated. Age, height and weight distribution did not differ significantly between groups and no significant differences in smoking history between power plant workers and controls were found. Table 1 presents descriptive information about the study group. The concentrations of environmental NO_2 ranged from 1.2 to 7.8 mg m^{-3} with a mean value of 3.9 ± 1.5 mg m^{-3}. The results of FEV_1 and FVC measurements were significantly lower in the power plant workers than in the controls ($P < 0.001$). In the power plant workers, a significant intercorrelation was found between FER (FER = FEV_1/FVC) and many of the variables. FER was significantly correlated with age ($P < 0.01$), environmental NO_2 concentration ($P < 0.001$), smoking ($P < 0.01$) and height ($P < 0.001$). Surprisingly, no significant associations were found between FER and weight ($P < 0.05$). A multiple linear regression model was developed including the variables that were considered to be potentially associated with the following outcomes: FER and age, NO_2 environmental concentration, smoking and height. The adjusted multiple linear regression model showed a *P* value < 0.001. The FER values were positively associated with younger age ($P < 0.05$), NO_2 environmental concentration ($P < 0.001$), smoking ($P < 0.05$) and height ($P < 0.001$) (Table 2).

Discussion

Our findings strongly suggest an association between NO_2 power plant emissions and FEV_1, FVC and FER values. The observed reduction in spirometric parameters may be due to the direct inflammatory action of NO_2 on lung mucosa [4]. Nevertheless, this study shows that occupational exposure to NO_2 is associated with a decrease in spirometric parameters, and consequently may result in a higher prevalence of respiratory diseases such as bronchial irritation and chronic obstructive pulmonary disease. Periodic spirometric measurements in power plant workers exposed to NO_2

Table 1. Demographic characteristics of the power plant workers and controls

Characteristic	All (*n* = 696)			Power plant workers (*n* = 347)			Controls (*n* = 349)		
	Mean	Standard deviation	Range	Mean	Standard deviation	Range	Mean	Standard deviation	Range
Age, years	42.3	6.3	28–58	41.3	5.5	29–55	43.3	5.6	29–58
Weight, kg	75.7	9.1	51–115	75	9.2	54–106	75.5	8.8	51–115
Height, cm	169.1	5.5	152–194	168.7	5.2	154–185	169.5	33.6	152–194
Smoking status									
Smokers	297			157			140		
Non-smokers	399			190			209		

Table 2. Results of the multiple linear regression model (n = 696)

Dependent variable: FER (model P value: 0.0000)

Parameter	Estimate	Standard error	T statistic	P value
CONSTANT	137.0	6.62	20.7	<0.001
NO_2 environmental concentrations	-9.9×10^{-4}	1.2×10^{-4}	−7.81	<0.001
Age	−0.09	0.03	−2.69	<0.01
Smoking	1.05	0.40	2.65	<0.01
Height	−0.195	0.04	−5.17	<0.001

emissions may be an effective means of detecting early signs of impaired respiratory health in this group of workers.

Key points

- Power plant workers are exposed to nitrogen dioxide in the workplace.
- This study showed an association between exposure to nitrogen dioxide and reduced spirometric parameters independent of age, height, weight and smoking status.
- Exposure to nitrogen dioxide may have an adverse effect on health outcomes in power plant workers.

Conflicts of interest

None declared.

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