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Lung function in Pakistani wood workers

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Abstract

The lung function impairment is the most common respiratory problem in industrial plants and their vicinity. Therefore, the purpose was to study the affects of wood dust and its duration of exposure on lung function. This was a matched cross-sectional study of Spirometry in 46 non-smoking wood workers with age range 20 – 60 years, who worked without the benefit of wood dust control ventilation or respiratory protective devices. Pulmonary function test was performed by using an electronic Spirometer. Significant reduction was observed in the mean values of Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and Maximum Voluntary Ventilation (MVV) in wood workers relative to their matched controls. This impairment was increased with the duration of exposure to wood industries. It is concluded that lung function in wood workers is impaired and stratification of results shows a dose-response effect of years of wood dust exposure on lung function.

Keywords: *Occupational hazards, pulmonary function, wood dust*

Introduction

The world community has been facing increasing risks of respiratory diseases due to the generation of smoke and dust in different industrial sectors. The wood processing industry is one of the largest manufacturing industries. Occupational exposures to wood dust may cause numerous health problems including the onset of acute or chronic respiratory diseases and lung function deficit. The lung function impairment is the most common occupational respiratory problem in industrial plants and their vicinity especially in the welding (Meo et al. 2003), cement (Meo et al. 2002) and wood industries sectors (Liou et al. 1996).

Wood is one of the most important renewable resources in the world and expands over approximately one-third of the earth's total landmass about 3.4 million km^2, and at least 1700 million m^3 are cultivated for industrial use each year. Industries in which a large amount of wood dust is produced include sawmills, dimension mills, furniture industries,

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cabinet making, and carpentry (International Agency for Research on Cancer [IARC] 1995).

Wood dust is a light brown or tan fibrous powder-like substance generated when timber is processed, while it is chipped, sawed, turned, drilled, or polished. Its composition varies considerably according to the species of trees and consists mainly of cellulose, hemi-cellulose, and lignin. The accessory substances or extractives are alkaloids, saponins, phenolic compounds especially catechols, quinones, stilbenes, terpenes, and furocoumarins, which are responsible for most toxic, irritant, and sensitizing effects (Woods & Calnan 1976).

At least two million workers in the European Union are employed in wood industries; they are exposed to airborne dust of different particle sizes, concentrations, and compositions (Kauppinen et al. 2000). Wood dust, endotoxins, and allergenic fungi are the main hazards found in wood working environments. Exposure to wood dust has long been associated with a variety of adverse health effects, including dry cough, malaise, chronic bronchitis, shortness of breath, chest pain, conjunctivitis, rhinitis, dermatitis, occupational asthma, allergic alveoli, headache and lung function deficits (Magnavita et al. 2002; Milanowski et al. 2002; Pontier et al. 2002; Roux et al. 2002). Keeping in view the available information, it is worthwhile to investigate the effects of wood dust on lung function in workers exposed to small-scale wood industries. In addition, our intention was to search for dose-response relationship between years of exposure to wood dust and lung function impairment. The present study attempts to minimize confounding interpretational factors by using matched controls, excluding smokers and workers with previous industrial exposure other than wood industries. Additionally, the workplace environment was approximately the same for all the subjects.

Subjects and methods

Subjects

The author visited the timber market Godhra camp, North Karachi, Pakistan, during the summer of July – August 2002 and interviewed approximately 72 small-scale wood industry workers. A comprehensive history was taken to determine whether they would be included in the study or not on the basis of the exclusion criteria. All the participants were questioned with regards to smoking cigarettes and other tobacco products and chewing tobacco or betel nut products. After the initial interviews 46 apparently healthy male wood workers with a mean age of 32.13 ± 1.87 years (mean ± SEM; range 20 – 60 years) with mean duration of exposure 5.52 ± 0.60 years (mean ± SEM; range 1 – 14 years) were selected. These wood workers worked for at least 8 – 10 h a day for six days per week, without using any personal protective measures. The control group was selected in a similar way from approximately 70 interviewed subjects, comprising finally 46 matched healthy men, mean age 33.28 ± 1.72 years (mean ± SEM; range 20 – 60 years). The control group was composed primarily of shopkeepers and salesmen. All subjects were individually matched for age, height, weight, and socio-economic status.

Exclusion criteria. Subjects with clinical abnormalities of the vertebral column, thoracic cage, neuromuscular diseases, known cases of gross anemia, diabetes mellitus, pulmonary tuberculosis, bronchial asthma, chronic bronchitis, bronchiectasis, emphysema, malignancy, drug addicts, cigarette smokers, tobacco chewers, those who had undergone vigorous exercise, abdominal, or chest surgery, and subjects exposed in any industry other than wood industry were also excluded from the study.

Methods

Small-scale wood industries

The small-scale wood factories are located at Godra camp, New Karachi, Pakistan, near the main road to attract the customers. The small-scale wood industrial units in Pakistan are different from large-scale industries in developing countries. These units consists of temporary shelters with 6–8 poles supporting a roof that was made up of old wooden material, and their walls were also made up of wooden boards; in a few units the roof was made up of old iron sheets. The numbers of workers in each unit was 10–15, and the overall physical condition of the workplace was unsatisfactory. No exposure control equipments such as exhaust ventilation were fitted in any of the small-scale wood industry units and teal was the most frequent type of wood used in these factories.

Spirometry. Spirometry was performed on an electronic Spirometer (Compact Vitalograph, UK). All pulmonary function tests were carried out at a fixed time of the day (9:00–13:00 h) to minimize the diurnal variation (Glindmeyer et al. 1994). The apparatus was calibrated daily and operated within the ambient temperature range of 20–25°C. The precise technique in executing various lung function tests for the present study was based on the operation manual of the instrument with special reference to the official statement of the American Thoracic Society of Standardization of Spirometry (1987). After taking a detailed history and anthropometric data, the subjects were informed about the whole maneuver. They were encouraged to practice this maneuver before doing the pulmonary function test. The test was performed with the subject in the standing position without using a nose clip. The test was repeated three times after adequate rest, and results were obtained, available in the Spirometer. These parameters were Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), Forced Expiratory Ratio (FEV_1/FVC), Forced Expiratory Flow ($FEF_{25-75\%}$) and Maximum Voluntary Ventilation (MVV).

Statistical analysis

Statistical analysis was conducted using a paired *t*-test (two-tailed). A level of statistical significance was established at a value of $p < 0.05$. The pulmonary function data were correlated against the duration of exposure. Linear regression was applied on this correlation and the equation $y = mx + c$ was derived with the correlation coefficient (*r*), where 'y' means Spirometric value, 'x' indicates years of exposure, and 'c' is a constant. The *p*-value determined the level of significance of the correlation. Linear regression was also applied to estimate the effect of wood dust exposure as a dichotomous variable. Dummy variable of zero was assigned for control group and one was assigned for exposed group.

Results

The results are presented for overall group and stratified according to duration of exposure to wood industry (less than 4, 4–8, and more than 8 years). In Tables I and II, the formal statistical comparisons of the 'matching' variables (age, height, and weight) were similar for the two groups and hence, statistical confirmation of this fact is not discussed.

Overall group results

Overall anthropometric and lung function data for wood workers and their matched controls are shown in Table I. Wood workers had statistically significant reductions in FVC, FEV_1 and

Table I. Anthropometric and lung function data between wood workers and their matched controls.

Parameter	Wood workers (mean ± SEM) ($n=46$)	Control subjects (mean ± SEM) ($n=46$)	Percentage change (%)	p value
Age (yr)	32.13 ± 1.87	33.28 ± 1.72	−3.45	NS
Height (cm)	165.04 ± 0.69	167.08 ± 0.83	−1.22	NS
Weight (kg)	65.69 ± 1.10	65.78 ± 1.55	−0.13	NS
FVC (litres)	3.37 ± 0.12	4.12 ± 0.10	−18.20	$p=0.001$
FEV_1 (litres)	2.61 ± 0.12	3.10 ± 0.09	−15.80	$p=0.001$
FEV_1/FVC%	77.34 ± 2.32	75.54 ± 1.61	+2.38	NS
$FEF_{25-75\%}$ (litres/s)	3.33 ± 0.20	3.30 ± 0.17	+0.90	NS
MVV (litres/min)	98.15 ± 4.57	114.43 ± 4.13	−14.22	$p=0.0005$

NS, non-significant.

Table II. Anthropometric and lung function data for wood workers with duration of exposure less than 4, 4–8 and greater than 8 years compared with their matched controls.

Parameter	Wood workers (mean ± SEM)	Control subjects (mean ± SEM)	Percentage change (%)	p value
Duration of exposure less than 4 years ($n=21$ in each group)				
Age (yr)	23.52 ± 1.34	25.42 ± 1.18	−7.47	NS
Height (cm)	165.57 ± 1.19	167.80 ± 1.42	−1.32	NS
Weight (kg)	64.66 ± 1.58	63.52 ± 2.16	+1.79	NS
FVC (litres)	3.84 ± 0.12	4.39 ± 0.16	−12.52	$p=0.002$
FEV_1 (litres)	3.05 ± 0.15	3.34 ± 0.12	−8.68	NS
FEV_1/FVC%	79.66 ± 3.67	76.95 ± 2.34	+3.52	NS
$FEF_{25-75\%}$ (litres/s)	4.00 ± 0.28	3.71 ± 0.22	+7.81	NS
MVV (litres/min)	114.61 ± 5.71	125.47 ± 4.52	−8.65	NS
Duration of exposure 4–8 years ($n=14$ in each group)				
Age (yr)	34.14 ± 3.12	34.57 ± 2.68	−1.24	NS
Height (cm)	165.92 ± 1.08	167.85 ± 1.42	−1.14	NS
Weight (kg)	68.35 ± 2.37	69.78 ± 3.51	−2.04	NS
FVC (litres)	3.48 ± 0.16	4.12 ± 0.18	−15.53	$p=0.005$
FEV_1 (litres)	2.74 ± 0.15	3.18 ± 0.14	−13.83	$p=0.02$
FEV_1/FVC%	79.35 ± 3.05	77.92 ± 2.58	+1.83	NS
$FEF_{25-75\%}$ (litres/s)	3.34 ± 0.29	3.47 ± 0.24	−3.74	NS
MVV (litres/min)	103.0 ± 5.71	119.71 ± 5.34	−13.95	$p=0.02$
Duration of exposure greater than 8 years ($n=11$ in each group)				
Age (yr)	46.00 ± 3.00	46.63 ± 3.00	−1.35	NS
Height (cm)	162.90 ± 0.99	164.72 ± 1.12	−1.10	NS
Weight (kg)	64.27 ± 1.62	65.00 ± 1.97	−1.12	NS
FVC (litres)	2.34 ± 0.15	3.61 ± 0.11	−35.18	$p=0.0005$
FEV_1 (litres)	1.61 ± 0.11	2.53 ± 0.15	−36.36	$p=0.0005$
FEV_1/FVC%	70.36 ± 5.29	69.81 ± 3.59	+0.78	NS
$FEF_{25-75\%}$ (litres/s)	2.03 ± 0.29	2.31 ± 0.39	−13.14	NS
MVV (litres/min)	60.54 ± 4.37	86.63 ± 9.56	−30.11	$p=0.05$

NS, non-significant.

MVV. The means for FEV_1/FVC% and $FEF_{25-75\%}$ were not significantly different. The mean duration of exposure in wood workers was 5.52 ± 0.60 years (mean ± SEM), range 1–14 years. The percentage change (average difference between wood workers and control subjects) is also shown in Tables I and II.

Duration of exposure less than 4, 4–8 and greater than 8 years. Table II summarizes the comparison of the anthropometric and lung function parameters between wood workers with duration of exposure less than 4, 4–8 and greater than 8 years compared with their matched controls. There was a significant decline for FVC, FEV_1 and MVV in wood workers and this decline is directly proportional to the period of exposure in wood industries. However, there were no significant differences in FEV_1/FVC%, and $FEF_{25-75\%}$ data relative to controls. The mean duration of exposure in wood workers was 1.76 ± 0.18 years, range 1–3 years; 6.28 ± 0.26 years, range 4–8 years; and 11.72 ± 0.35 years, range 10–14 years for wood workers with duration of exposure less than 4, 4–8, and greater than 8 years respectively.

Regression analysis

Regression analysis for FVC, FEV_1, $FEF_{25-75\%}$ and MVV (Figures 1, 2, 4, 5) showed significant negative correlation indicating that increased duration of exposure to wood dust decreased these lung function parameters. The R^2 and p values for FVC R^2 0.5216, $p = 0.0001$; FEV_1 R^2 0.4692, $p = 0.0001$; $FEF_{25-75\%}$ R^2 0.3157, $p = 0.0001$; and MVV R^2 0.4681, $p = 0.0001$. However, such correlation was not observed for FEV_1/FVC% (Figure 3) R^2 0.0479, $p = 0.072$.

Additionally, linear regression was applied; regression coefficient and 95% confidence interval was obtained to estimate the effect of wood dust exposure as a dichotomous variable. The results for FVC, FEV_1, FEV_1/FVC%, $FEF_{25-75\%}$ and MVV presented in regression coefficient estimates and 95% confidence interval are shown in Table III. The results showed significant correlation for FVC, FEV_1 and MVV. However, non-significant regression coefficient was observed for FEV_1/FVC% and $FEF_{25-75\%}$.

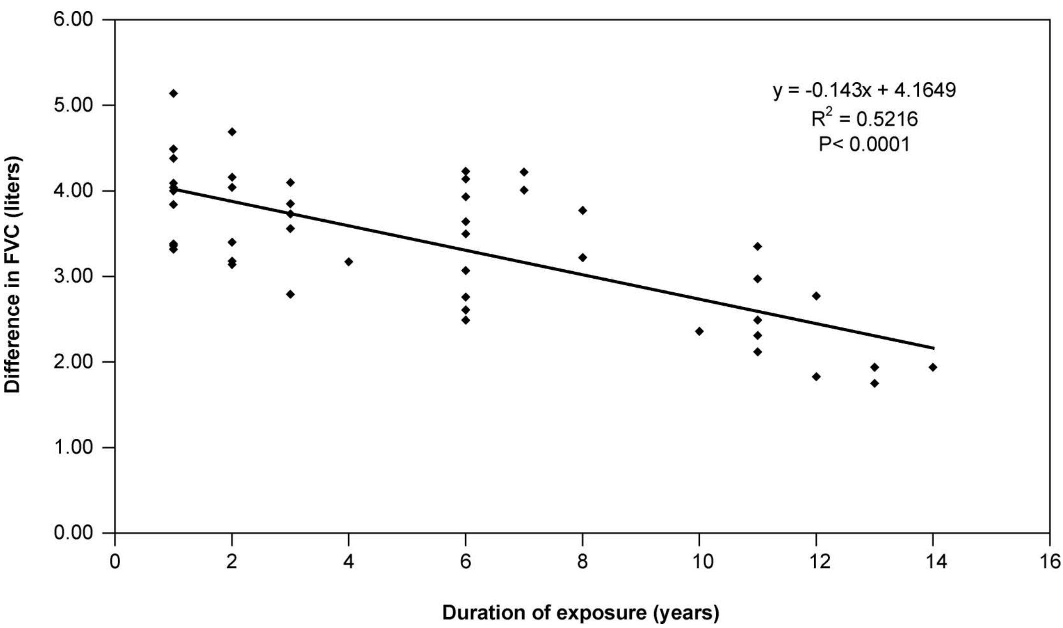

Figure 1. Regression analysis for individual differences in the Forced Vital Capacity (FVC) between wood workers against duration of exposure. A significant negative correlation was found, indicating that increased duration of exposure to wood dust decreased the FVC.

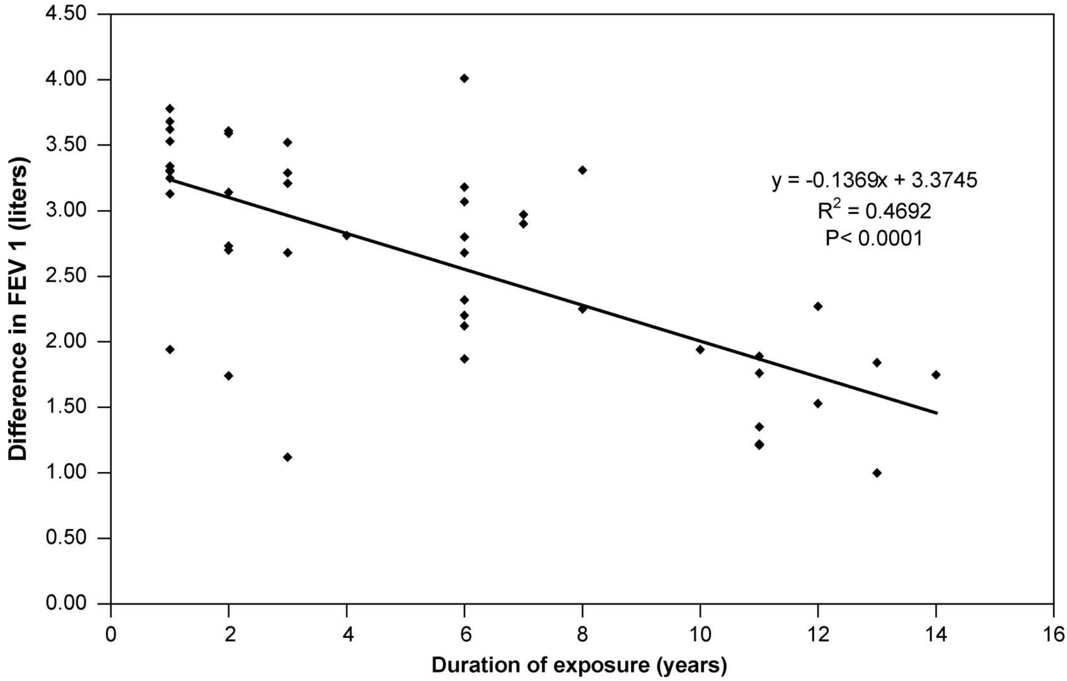

Figure 2. Regression analysis for individual differences in the Forced Expiratory Volume in one second (FEV_1) between wood workers against duration of exposure. A significant negative correlation was found, indicating that increased duration of exposure to wood dust decreased the FEV_1.

Discussion

In the present study, numerous factors were considered which greatly influence the lung functions including age, height, weight and socio-economic status. However, in previous studies many authors failed to consider these variables. The present study was attempts to minimize confounding interpretational factors by using matched controls, excluding smokers, workers with previous industrial exposure other than wood industries, and the workplace environment was approximately consistent for all the subjects. A second point deserving to be discussed is that this study was conducted to determine the lung functions by using Electronic Spirometer in workers who worked in small-scale wood industries on almost similar types of wood without using respiratory protective measure. However, keeping in view the well designed study protocol, we excluded a sizeable number of workers and were limited to finally recruiting 46 subjects in each group.

The present study demonstrates a strong association with a dose-effect between wood dust exposure and decreased pulmonary function; impairment in wood workers is directly proportional to the duration of exposure. Wood workers with exposures longer than 8 years showed a significant reduction in FVC, FEV_1 and MVV relative to controls. Similarly, regression analysis between lung function parameters and duration of exposure to wood dust was also performed. This indicates a significant positive correlation that, increased duration of exposure to wood dust decreased the lung function indices.

Milanowski et al. (2002) reported a lower FVC and FEV_1 values in woodworkers compared to controls and also demonstrated a significant pre-shift, post-shift decline in FVC, FEV_1,

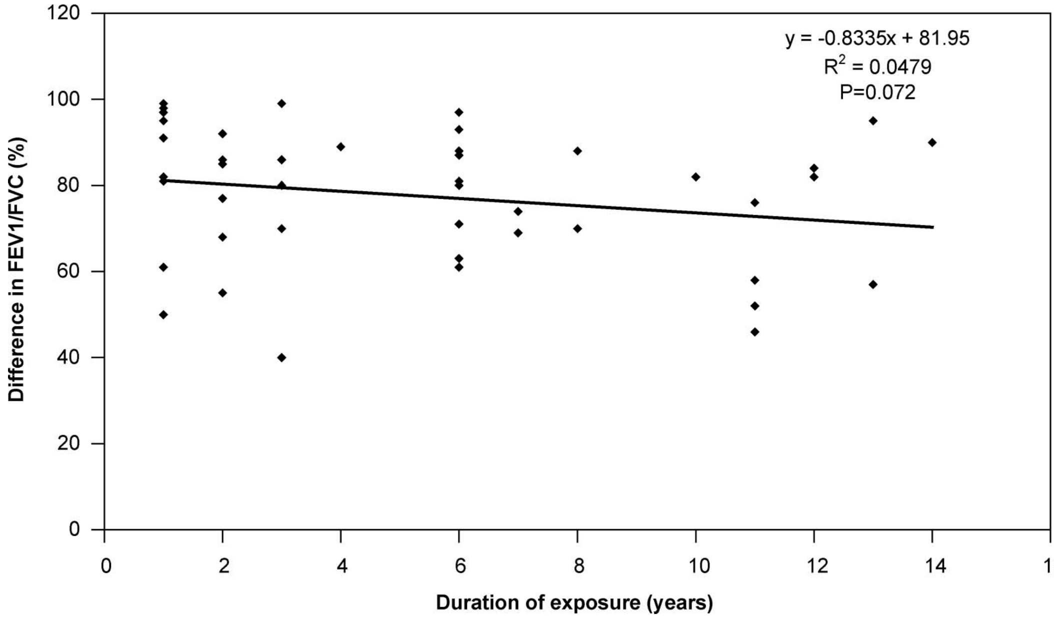

Figure 3. Regression analysis for individual differences in the Forced Expiratory Ratio ($FEV_1/FVC\%$) between wood workers against duration of exposure. A non-significant correlation was observed, indicating that increased duration of exposure to wood dust not significantly decreased the $FEV_1/FVC\%$.

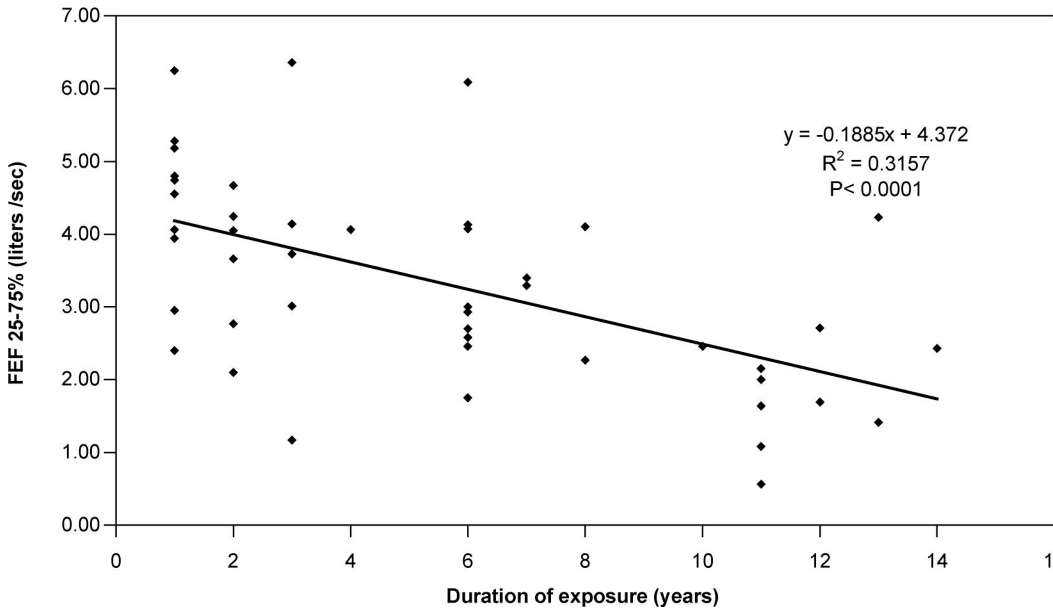

Figure 4. Regression analysis for individual differences in the Forced Expiratory Flow 25 – 75% ($FEF_{25-75\%}$) between wood workers against duration of exposure. A significant negative correlation was observed, indicating that increased duration of exposure to wood dust significantly decreased the $FEF_{25-75\%}$.

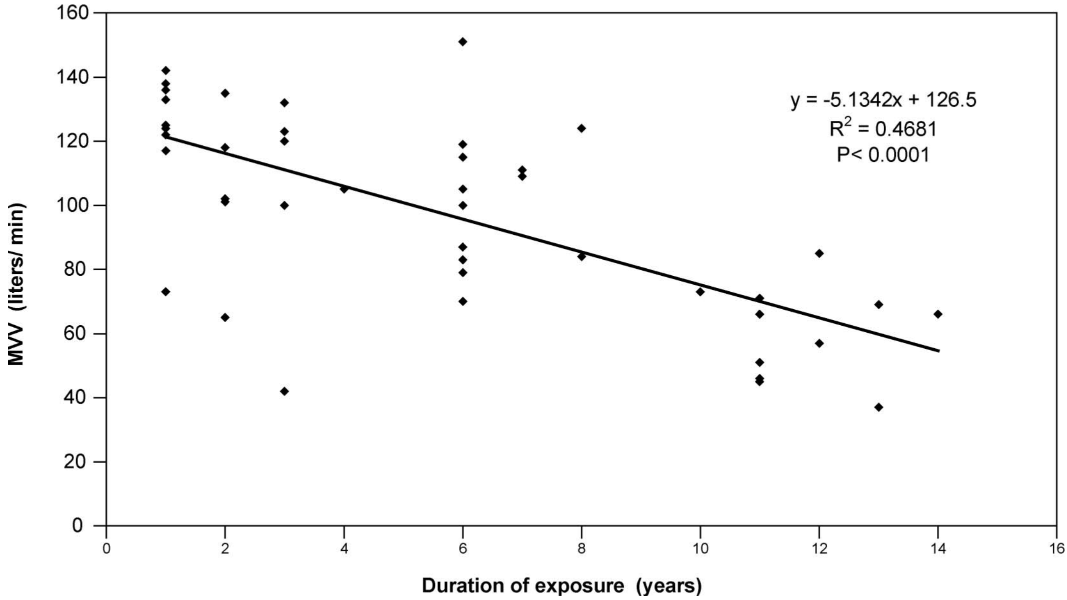

Figure 5. Regression analysis for individual differences in the Maximal Voluntary Ventilation (MVV) between wood workers against duration of exposure. A significant negative correlation was observed, indicating that increased duration of exposure to wood dust significantly decreased the MVV.

Table III. Regression coefficient and 95% confidence interval for control and wood workers.

	Control subjects ($n = 46$)		Wood workers ($n = 46$)	
Parameter	Reg. Coeff.	95% CI	Reg. coeff.	95% CI
FVC (litres)	4.12	3.89 – 4.35	3.37	2.82 – 3.92
FEV_1 (litres)	3.10	2.88 – 3.31	2.61	2.13 – 3.13
FEV_1/FVC%	75.54	71.57 – 79.51	77.34	67.75 – 86.99
$FEF_{25-75\%}$ (litres/s)	3.30	2.92 – 3.68	3.33	2.41 – 4.24
MVV (litres/min)	114.43	105.77 – 123.09	98.15	77.24 – 119.05

Reg. coeff, Regression coefficient; 95% CI = 95% Confidence Interval.

FEV_1/FVC, and peak expiratory flow (PEF) among wood workers. Our results correlate with the results observed by Milanowski et al. (2002). However, in the present study we did not observe the values based on the pre-shift and post-shift changes, but we observed overall decline for FVC, FEV_1 and MVV in wood workers.

Milanowski et al. (1996) showed a significant reduction of FVC, FEV_1, FEV_1%VC and PEF in furniture workers than controls. Mandryk, et al. (1999) reported that a mean percentage cross-shift decrease in lung function parameters; FVC, FEV_1, FEV_1/FVC, $FEF_{25-75\%}$ for wood workers compared with the controls. Similarly, Beretic-Stahuljak et al. (1988) found a dose response relationship between post-shift decreases in FEV_1 over a working day when exposed to wood dust. Our results are in conformity with the former results observed by Milanowski et al. (1996); Mandryk et al. (1999); and Beretic-Stahuljak et al. (1988).

In contrast to our results Ahman et al. (1996) made lung function tests on 40 wood working teachers and observed no relationship between measured total dust exposure and change in FVC, FEV_1 and FEV_1/FVC. The most probable reasons for no change in lung function parameters are that the wood working teachers were not professional laborers of the wood industries, their working environment was quite clean, and they performed their duties on a limited lecture basis. Therefore, the present study results are in contrast to the results observed by Ahman et al. (1996).

Liou et al. (1996) demonstrated that the pulmonary function parameters MMF, PEFR, and $FEF_{25\%}$ were significantly lower in the exposed workers than in controls for both smokers and non-smokers and also showed a declining trend with increasing exposure levels. Similarly, Al Zuhair et al. (1981), Holness et al. (1985), Carosso et al. (1987), Herbert et al. (1995), and Schlunssen et al. (2002) showed a cross-shift decrease in forced expiratory volume in one second (FEV_1) among wood workers.

In addition, Noertjojo et al. (1996) reported that wood workers had significantly greater declines in FVC and FEV_1 compared with office workers adjusted for age and smoking. A dose-response relationship was also observed between the level of exposure and the annual decline in FVC. Dahlqvist et al. (1992) showed signs of a mild obstructive impairment with a decreased FEV_1 and this decline was more during the working week.

Hedenstierna et al. (1986) studied the pulmonary function of wood trimmers and reported that the FVC and FEV_1 were reduced in wood workers. The present study confirms the findings of others and suggests that wood dust adversely affects the lung function parameters FVC, FEV_1 and MVV. The mechanism of pathogenesis involving the lungs in wood workers is due to exposure to airborne dust of different particle sizes, concentrations and compositions, these structural components of wood are responsible for most toxic, irritant, and sensitizing effects (Kuruppuge 1998) which become a cause of impairment and worsening of lung function.

While discussing the patho-physiological aspects of drop in the value of lung function parameters FVC is important in acute and chronic respiratory care (Shapiro et al. 1985) and decreased in pulmonary obstruction, emphysema, pleural effusion, pneumothorax and pulmonary edema (Keele et al. 1982). Similarly, the forced expiratory volume in one second (FEV_1) is low in obstructive lung diseases and in reduced lung volume (Mann et al. 1995). The decline of FEV_1 is a convenient standard against which we can measure marked declines in persons who have a history of chronic obstructive pulmonary disease (COPD) or subject to occasional exposure to pollutants in the environment (Enright & Hodgkin 1997). Similarly, maximal voluntary ventilation (MVV) reflects the function of the entire ventilatory apparatus and depends upon the compliance of the thoracic wall and lungs, airway resistance and muscular force. MVV is profoundly reduced in patients with airway obstruction or in emphysema (Shapiro et al. 1985; Enright & Hodgkin 1997).

Conclusion

In view of the patho-physiological aspects and drop in FVC, FEV_1 and MVV parameters, our results suggests that the wood dust adversely affects the lung function and this impairment is associated with dose-effect response of years of exposure to wood dust. All these facts allow us to conclude that the findings are of importance in that the study highlights the need to reduce exposure and shows the magnitude of the effect in a population. It is advisable therefore, that health risk should be reduced by the mutual collaboration between health officials, wood workers and their management to adopt technical preventive measures, such as ventilated work areas and wearing appropriate respiratory protective equipment. It is also suggested that these workers must undergo pre-employment and periodic medical surveillance tests. These measures will help to identify susceptible workers so they can take additional preventive measures as well as medication.

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