Symptoms and Pulmonary Function in Western Red Cedar Workers Related to Duration of Employment and Dust Exposure

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ABSTRACT. Measurements of total dust concentration were made in a western red cedar sawmill that employed 701 workers. Both area sampling and personal sampling of total dust were done over an 8-hr shift corresponding to job descriptions and locations to assign each worker an exposure level. A total of 652 (93%) of the workers completed a respiratory-occupational questionnaire and performed spirometry, of whom 334 were assigned an exposure level. Dust exposure ranged from undetectable to 6.0 mg/m^3 with a median exposure level of 0.2 mg/m^3. Only 10% of the workers with an assigned exposure level were exposed to more than 1.0 mg/m^3. Work-related asthma, defined as symptoms of asthma which improved on days off work, was reported by 52 workers (8.0%) and was more prevalent after 10 or more yr of employment. Chronic cough, dyspnea, persistent wheeze, and physician-diagnosed asthma were unrelated to either work duration or exposure. Levels of forced vital capacity (FVC) and forced expiratory volume in 1 sec ($FEV_{1.0}$) were lower with dust concentrations greater than 2.0 mg/m^3, controlling for age and smoking; maximum mid-expiratory flow rate ($FEF_{25-75\%}$) and $FEV_{1.0}$/FVC were unrelated to dust exposure concentration. Work-related symptoms of eye irritation were seen more commonly with exposure to dust concentrations of 3.0 mg/m^3 or more. It is concluded that symptoms of work-related asthma in red cedar workers are more common after 10 yr of exposure, and that levels of pulmonary function are lower with higher wood dust exposures.

EXPOSURE to western red cedar (*Thuja plicata*) dust is a well-recognized cause of occupational asthma.[1,2] Estimates of the prevalence of occupational asthma in western red cedar workers have ranged from 1.1% in 405 sawmill workers[3] to 13.5% in 74 shake mill workers.[4] It is possible that these differences in estimated prevalences are due to different levels of dust exposure.

In 1982, we started a 3-yr longitudinal study of workers in a western red cedar sawmill. The sawmill workers were compared with a group of office workers not exposed to air contaminants at work.[5] We found that the cedar workers had significantly higher prevalences of respiratory symptoms and of symptoms compatible with work-related asthma compared to the office workers. Moreover, levels of lung function were significantly lower and the prevalence of bronchial hyperreactivity significantly higher among the cedar workers. In this report we explore the relationship between the level of exposure, as reflected by both duration of employment and dust concentration, and both the prevalence of respiratory symptoms and illnesses, and levels of lung function in cedar sawmill workers.

Methods

Study subjects. Of the 701 available male workers in the sawmill, 652 (93%) took part in the study. Nonparticipants tended to be older than participants (47.6 ± 12.9 yr vs. 43.4 ± 13.4 yr) and were more likely to be white (98% vs. 78%). Nonwhite workers consisted primarily of East Indians and, as a group, made up 22% of the 652 participating workers.

Questionnaire. All workers who agreed to participate completed a questionnaire administered by trained interviewers and underwent spirometric testing. The questionnaire combined the questions from the American Thoracic Society's adult respiratory questionnaire (ATS-DLD-78)[6] and detailed questions on occupational history. The following were defined from the questionnaire responses: (1) chronic cough, if cough was present on most days of the week at least 3 consecutive months during the year; (2) chronic phlegm production, defined in a manner analogous to chronic cough; (3) dyspnea, if shortness of breath was present when hurrying on level ground or walking up a slight hill; (4) persistent wheeze, if wheeze was reported with colds and occasionally apart from colds, or wheeze was present on most days or nights; and (5) physician-diagnosed asthma. Questionnaire-defined asthma ("asthma") and questionnaire-defined, work-related asthma (work-related "asthma") were defined as recommended by Brooks.[7]

"Asthma" was defined if at least four of the following five symptoms were reported:

1. regularly noticed wheezing, cough, phlegm, shortness of breath or chest tightness;
2. cough on most days;
3. wheeze with a cold or apart from a cold on most days or nights;
4. attacks of chest tightness with shortness of breath; and/or
5. shortness of breath upon hurrying on the level or walking up a slight hill.

Work-related "asthma" was defined if all of the following was reported:

1. diagnosis of "asthma" as defined above;
2. symptoms not present before sawmill employment started;
3. symptoms improve on weekends off *or* symptoms improve on longer holidays.

Work-related nasal symptoms were defined as having sneezing or an itchy or runny nose which either improved on days off or on long holidays. Work-related eye symptoms were defined as burning, itchy, or runny eyes which either improved on days off or on long holidays.

Pulmonary function. Spirometry was performed at the work site using a 13.5 L Collins waterseal spirometer. Subjects performed the forced vital capacity (FVC) maneuver seated while wearing noseclips. Repeated FVC maneuvers were performed until at least three acceptable curves were obtained. The ATS Snowbird Workshop criteria[8] were used to define acceptable curves. Analysis of FVC was performed on the curve with the largest FVC and analysis of forced expiratory volume in 1 sec ($FEV_{1.0}$) on the curve with the largest $FEV_{1.0}$. Maximum mid-expiratory flow rate ($FEF_{25-75\%}$) and the $FEV_{1.0}$/FVC ratio were measured from the tracing with the largest sum of $FEV_{1.0}$ and FVC. Measurements were converted to BTPS.

Industrial hygiene measurements. Measurements of total airborne dust concentration were performed by the Engineering Department of the Workers' Compensation Board of British Columbia using both personal and area sampling. Samplers consisted of filter cassettes 37 mm in diameter with a 0.8 μm pore size through which air at 2 L/min was pumped. Dust concentration expressed in mg/m^3 was calculated from the change in weight of the filter divided by the volume of air sampled. Sampling was done over an entire 8-hr shift to correspond to as many job descriptions and locations as possible. Area sampling was done if the worker was relatively immobile in his job or if the weight and bulk of the sampler might have hindered a worker's safety; otherwise personal sampling was done. A total of 104 samples were obtained during the time of the study. Since the sampling method was unable to distinguish wood dusts from other particulates and the study was concerned with wood dust exposure, workers likely to have exposure to particulates other than wood dust did not have exposure scores assigned; these workers included maintenance workers, welders, and oilers. After the exclusions, 78 samples, 46 by area sampling and 32 by personal sampling, were considered to contain only wood dust. Workers who had the same job title and job location were considered to have the same level of dust exposure. Using this procedure it was possible to assign 334 of the workers a level of exposure.

Analysis. Because of the small number of workers exposed to high dust levels, differences in the prevalence of symptoms by dust level were tested with Fisher's exact test.[9] Multiple logistic regression[10] was used to test associations between symptoms and years of employment while controlling for covariates such as age, race, and cigarette smoking. Associations between levels of pulmonary function and years of employment or dust exposure level controlling for the same covariates were tested using multiple linear regression techniques.[11] Age was entered into the equations as a continuous variable. Race was entered as an indicator variable identifying nonwhite workers. Indicator variables for exsmoking and current smoking were entered to control for cigarette smoking. To avoid making assumptions about the linearity of the relationships between either employment duration or dust exposure concentration and levels of pulmonary function, duration and concentration were categorized and indicators of the categories entered into the regression models. This also allowed for testing of threshold effects or dose-response relationships.

Results

Total dust exposure ranged from undetectable to a concentration of 6.0 mg/m^3. In the 334 workers with assigned dust exposure levels, the median dust exposure was 0.21 mg/m^3 and the mean, 0.46 mg/m^3. Only 33 (10%) with an assigned level of exposure were exposed to more than 1.0 mg/m^3 and, of these, only 13 (3.9%) had an exposure greater than 2.0 mg/m^3 (Table 1). The total group of 652 workers was employed for an average of 12.7 yr (median 9.0 yr). Level of exposure was not related to the number of years of employment (Table 2).

Table 1.—Employee characteristics by dust exposure concentration in the 334 workers with exposure data

	Dust (mg/m^3)			
	<1.0	1.0-1.9	≥2.0	All
Number	301	20	13	334
Current smokers(%)	33	50	62	35
Nonwhite(%)	31	15	0	29
Age (mean)	41	46	44	41
Years employed (median)	6	12	5	6

Table 2.—Employee characteristics by years of sawmill employment in all 652 workers

	Years				
	0-4	5-9	10-19	≥20	All
Number	209	135	121	187	652
Current smokers(%)	29	34	36	36	33
Nonwhite(%)	27	33	31	0	22
Age (mean)	33	40	45	56	43
Dust exposure*	0.21	0.21	0.28	0.25	0.21

*Limited to 334 workers

Work-related "asthma," as defined previously, was present in 8.0% of the workers. The prevalence of work-related "asthma" was highest after 10 yr of employment (Table 3). Two workers out of the 13 with exposure to greater than 2.0 mg/m^3 of total dust reported work-related "asthma." While this percentage is higher than in the lower exposure categories (Table 4), the number of workers is too few for meaningful analysis. Both of these workers were nonsmokers and had a dust exposure level of 3.4 mg/m^3. Work-related eye symptoms were unrelated to employment duration but were increased with dust concentrations above 2.0 mg/m^3 ($P = .02$). The four workers on which this association was based were exposed to 3.0 mg/m^3 of dust or more. Prevalence of cough, dyspnea, persistent wheeze, and "asthma" increased with increases in dust exposure level (Table 4), but cigarette smoking also increased with dust level (Table 1).

Multiple logistic regression analysis, controlling for cigarette smoking, confirmed the association between duration of employment and work-related "asthma."

Table 3.—Prevalence (%) of symptoms* by years of sawmill employment in all 652 workers

	Years				
	0-4	5-9	10-19	≥20	All
Cough	15	19	17	17	17
Phlegm	12	19	15	20	16
Dyspnea	19	21	25	38	26
Persistent wheeze	13	17	12	17	15
M.D. asthma	3	5	6	5	5
"asthma"	9	8	11	13	10
Work-related:					
"Asthma"	5	6	10	12	8
Eye symptoms	6	11	8	9	8
Nasal symptoms	12	17	12	16	14

*See text for definitions.

Table 4.—Prevalence (%) of symptoms* by dust exposure concentration in 334 workers

	Dust (mg/m^3)			
	<1.0	1.0-1.9	≥2.0	All
Cough	16	20	23	16
Phlegm	17	15	15	17
Dyspnea	22	30	39	23
Persistent wheeze	12	10	23	13
M.D. asthma	4	5	0	4
"asthma"	8	5	15	8
Work-related:				
"Asthma"	6	5	15	6
Eye symptoms	8	5	31	9
Nasal symptoms	13	15	15	13

*See text for definitions.

Estimated odds of work-related "asthma" derived from the regression model were 2.1 times higher (95% confidence interval 1.2 to 3.9) for workers with 10 or more yr of employment than for workers with less than 10 yr. Odds of cough, dyspnea, persistent wheeze, or "asthma" were not increased with higher levels of dust exposure after controlling for cigarette smoking.

Levels of pulmonary function were related to dust exposure concentration but not to duration of employment, controlling for height, age, cigarette smoking, and race (Table 5). $FEV_{1.0}$ and FVC were significantly lower in workers exposed to dust levels of 2 mg/m^3 or more. No association was present between levels of $FEF_{25-75\%}$ or $FEV_{1.0}$/FVC and dust exposure.

Discussion

In this survey of a western red cedar sawmill, exposure to total dust levels of greater than 2.0 mg/m^3 was associated with lower levels of FVC and $FEV_{1.0}$ and exposure to greater than 3.0 mg/m^3 was associated with a higher prevalence of work-related eye symptoms. Employment for 10 or more yr was associated with more work-related symptoms of asthma. Dust concentrations in general were relatively low. Brooks et al.[4] reported levels of total dust in a western red cedar shake mill of up to 31.9 mg/m^3. Median dust level in that study was 1.59 mg/m^3 and was much lower than the mean of 4.72 mg/m^3,

Table 5.—Estimated decrement* in levels of pulmonary function related to dust exposure level and to years of employment

	Dust level (mg/m^3)		Years of employment	
	1.0-1.9	≥2.0	10-19	≥20
No. of subjects	20	13	121	187
$FEV_{1.0}$ (ml)	−148	−337†	26	44
FVC (ml)	−187	−412†	31	60
$FEF_{25-75\%}$ (ml/sec)	−214	−274	49	−48
$FEV_{1.0}$/FVC (%)	−0.27	−0.60	0.0	−0.1

*Estimated from multiple linear regression models controlling for height, age, race, and cigarette smoking. For dust levels, decrement is difference in mean levels between subjects exposed to the specified levels and those exposed to less than 1.0 mg/m^3 based on the 334 workers with an assigned dust exposure level. For duration of employment, decrement is difference in mean levels between subjects working for the specified periods of time and those working for less than 10 yr based on all 652 workers.
†Two-sided P value < .05.

implying that only a few shake mill workers had very high exposures. Respirable dust was much lower with a median level of 0.14 mg/m^3.

This is the only report in which the association between levels of pulmonary function and dust exposure in red cedar workers has been evaluated. Exposure to levels of total dust above 2.0 mg/m^3 was associated with lower levels of both $FEV_{1.0}$ and FVC but not of $FEF_{25-75\%}$ or $FEV_{1.0}$/FVC. This association was based on only 13 workers with exposure to more than 2.0 mg/m^3 of dust and must therefore be interpreted cautiously. If the association is a real one, it is surprising that the pattern is one of restriction (low $FEV_{1.0}$ and low FVC) rather than of airflow limitation. Hypersensitivity pneumonitis, which might produce this pattern, has been reported with exposure to maple[12] or California redwood bark,[13] but has not been reported with cedar.

"Asthma" and work-related "asthma" were defined from specific patterns of questionnaire responses. More than twice as many workers fulfilled the questionnaire criteria for "asthma" than claimed a physician's diagnosis of asthma. We suspect that the criteria for work-related "asthma" identify some workers without red cedar asthma, but conversely, that those with red cedar asthma are unlikely to be missed. The 8.0% prevalence of work-related "asthma" is probably, therefore, an overestimate of the prevalence of red cedar asthma even in this "survivor" population. A prevalence of 13.5% was found in the survey of cedar shake mill workers, where work-related asthma was defined by the same questionnaire criteria used here but with the additional provision that a 10% fall in $FEV_{1.0}$ from the Monday preshift baseline level occurred during the work week.[4] This difference in prevalence is likely due to the large difference in dust concentration in the two mills.

In a study of patients with red cedar asthma, it was found that the group with recurrent attacks of asthma which continued after leaving work had a longer period of exposure.[14] Since work-related "asthma" was seen more often with 10 or more years of exposure, this suggests that many of the workers who may have red cedar asthma and are still employed at this sawmill will continue to have asthma after they leave employment.

Both duration of employment and total dust level measured over an 8-hr shift were used as the indices of cedar dust exposure. Neither may be a good reflection of the dose characteristics which result in red cedar asthma or other respiratory illness. Work duration reflects chronicity of exposure, but long duration in some instances might be associated with exposure to harmless levels of dust and vice versa. Also, current dust level may not adequately reflect exposure in previous years. Both indices of exposure, then, likely result in some misclassification of the true dose. The effect of misclassification, if random, would be to underestimate the strength of the associations[11] between exposure and either symptoms or levels of pulmonary function, and would not therefore invalidate the findings. Also, workers with red cedar asthma are affected by low concentrations of cedar dust.[2] Therefore, unless sensitization to cedar is dependent on exposure level and exposure to the levels resulting in sensitization has continued, we would be unlikely in a cross-sectional study to find an association between asthma and dust exposure level. Selective continued employment of the relatively healthy workers may also have contributed to an underestimation of effects of cedar sawmill employment.

We conclude that even at the low dust concentrations measured in this sawmill, the prevalence of symptoms consistent with red cedar asthma was high. Symptoms of work-related eye irritation and lower levels of pulmonary function were more common with exposure to higher levels of total dust. Data from a prospective study of workers in this sawmill will hopefully be helpful in identifying the exposure or host factors which result in red cedar asthma.

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