Respiratory Health in Asbestos-Exposed Ironworkers

Adrian Z. Rocskay, PhD, Michael R. Harbut, MD, MPH, Margaret A. Green, MD, MPH, David L. Osher, MD, and Edward T. Zellers, PhD

This study aimed to determine the prevalence of respiratory morbidity among asbestos-exposed ironworkers and to determine the relationship between respiratory morbidity indices and length of exposure. A medical screening provided information on chest radiographic abnormalities, pulmonary function, rales, finger clubbing, and respiratory symptoms for 547 asbestos-exposed ironworkers. Union pension records furnished data on length of exposure. The study group exhibited an increased prevalence of small irregular opacities, pleural plaques, and pleural thickening on chest x-ray; reduced FEF_{25-75}; rales; and respiratory symptoms. After controlling for the effect of cigarette smoking and age, years since joining the ironworkers union were significantly associated with profusion, pleural thickening, pleural plaques, rales, percent predicted FVC, reduced FVC, reduced FEV_1, reduced FEV_1/FVC, and dyspnea grades I, II, III, and IV.

***KEY WORDS:* asbestosis, pleural abnormalities, parenchymal abnormalities, pulmonary function, ironworkers, welding exposures**

INTRODUCTION

Ironworkers comprise the skilled construction trade whose members work with structural steel. From the 1930s to the 1970s, ironworkers had exposure to airborne asbestos fibers during new construction if they sprayed or sawed through asbestos-containing building materials, such as insulation, fireproofing, or panels. During renovation or demolition, many ironworkers were exposed to asbestos when they removed asbestos-containing material from structural steel to access the underlying metal for welding or torch cutting. Movement of their bodies and equipment across the trusses of buildings often disturbed the asbestos in place on the structural steel. Ironworkers used asbestos fire blankets to shield the material adjacent to welding from ignition. They also frequently worked in close proximity to pipecoverers, asbestos insulation workers, and other construction trades that handled asbestos-containing material.

Among the skilled construction trades, studies have established a strong link between pulmonary disease and the sort of intermittent exposure to airborne asbestos just described [Sprince et al., 1985; Kennedy et al., 1991; Schwartz et al., 1990; Welch et al., 1994; Demers et al., 1990]. Fischbein et al. [1991] reported asbestos-related lung disease among ironworkers in the New York metropolitan area. They concluded that the level of respiratory illness found in the New York cohort, coupled with the large number of workers active in the trade in the United States, justified additional investigations of other groups of ironworkers.

To that end, the current paper examines data collected during a screening for asbestos-related lung disease among ironworkers in Michigan. This study seeks to determine the prevalence of respiratory morbidity among these ironworkers, and the relationship between respiratory morbidity indices and length of asbestos exposure.

Center for Occupational and Environmental Medicine, Southfield, Michigan (A.Z.R., M.R.H., M.A.G.).
Department of Environmental and Industrial Health, School of Public Health, University of Michigan, Ann Arbor (A.Z.R., E.T.Z.).
Division of Occupational Health, Michigan Department of Public Health, Westland (A.Z.R.).
Providence Hospital, Southfield, Michigan (D.L.O.).
Address reprint requests to Adrian Z. Rocskay, Division of Occupational Health, Michigan Department of Public Health, 7325 Middlebelt Road, Westland, MI 48185.

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METHODS

Screening Protocol

Each of the 3,119 members of Local 25 of the International Association of Bridge, Structural, and Ornamental Ironworkers of eastern Michigan received an invitation by mail to participate in the screening. The union solicited participation of the ironworker subpopulation with asbestos exposure, since some members had not encountered asbestos in their jobs. The union targeted ironworkers identified by foremen as having asbestos exposure. The screening locations at Detroit, Lansing, and Saginaw accommodated the geographic dispersion of members.

Five hundred and forty-seven ironworkers (17.5% of the membership) reported for screening. According to the union, these members constituted almost all ironworkers with a history of asbestos exposure. All participants were men and 97.9% were Caucasian. Screening consisted of a chest X-ray, pulmonary function test, physical exam, and medical questionnaire. Each subject signed an informed consent document for the medical screening. The University of Michigan School of Public Health's Human Subjects Review Committee approved the protocol for the overall study.

Chest X-Ray

A 14 × 17-inch posteroanterior chest radiograph was taken of each subject. Two B readers certified by the National Institute for Occupational Safety and Health (NIOSH) independently evaluated the chest film according to the International Labour Classification of Radiographs of Pneumoconioses [International Labour Office, 1980]. The B readers had no knowledge of the clinical status or exposure history of the subjects. The lower of the two B readings was selected for each chest X-ray variable. Profusion was coded on a 12-point scale with 0/0 assigned 0, 0/1 assigned 1, 1/0 assigned 2, and so forth. Comparing the evaluations of the two B readers, crude agreement (i.e., the percentage of tied pairs) was 85% for primary shape/size, 55% for profusion, 84% for any pleural abnormality, 81% for pleural thickening, 80% for pleural plaques, and 97% for pleural calcification. Eighty-two percent of the paired readings fell within one profusion category of each other.

Pulmonary Function Testing

A technician certified by NIOSH performed the pulmonary function testing (PFT). The spirometers used were the Medical Graphics Model 1070, Jones Pulmonaire, and Spirotech S400, Version 4F. Calibration of the spirometers followed American Thoracic Society guidelines [American Thoracic Society, 1987]. The measures of pulmonary function were forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV_1), FEV_1/FVC, and mean forced expiratory flow during the middle half of the FVC (FEF_{25-75}). The predicted values of Miller et al. [1980] were used to calculate the percent of the predicted value and to determine whether the measured value was reduced, that is, below the lower one-sided 95% confidence limit of the predicted value for the reference group. For the 105 subjects suspected of having respiratory disease who received a follow-up PFT within 1 year of their screening PFT, the coefficients of variation for the PFT variables were 6.8% for FVC, 6.6% for FEV_1, 0.4% for FEV_1/FVC, and 13.1% for FEF_{25-75}.

Physical Exam

A physician certified in occupational medicine or a nurse performed a physical exam to identify rales and finger clubbing. Rales were defined as end-inspiratory fine crackles at the lung bases that do not clear up with cough.

Medical Questionnaire

Questions from the Epidemiology Standardization Project [Ferris, 1978] were administered to ascertain respiratory symptoms, smoking status (current, former, or never smoker), and number of cigarette pack-years. The data of Petersen and Castellan [1984] supplied the expected prevalences of the respiratory symptoms among blue-collar workers unexposed to pulmonary toxicants. The respiratory symptom chronic cough referred to cough on most days for at least 3 months in a row during the year for at least 2 years. Chronic phlegm meant bringing up phlegm or sputum from the chest at the same minimum frequency. Chronic bronchitis indicated both chronic cough and chronic phlegm. Wheezing was defined as breathing difficulty with a whistling sound apart from colds. Shortness of breath, separate from wheezing, was coded on a five-grade scale of increasing intensity [Fletcher, 1952].

Exposure Assessment

Union pension records were used to calculate three measures of asbestos exposure: years since joining union, years in trade, and hours in trade. Because the three exposure measures were highly associated with each other ($p < 0.001$ in three simple regressions; $r^2 = 0.73$, 0.86, and 0.87, respectively) and because they had similar associations with respiratory morbidity (e.g., for the two least correlated exposure measures, 18 of the 22 simple regressions with the respiratory morbidity indices did not differ with respect to the significance of the exposure variable), associations with respiratory morbidity are reported for only years since joining union, the exposure measure that overall provided the strongest correlations with the disease endpoints.

At the start of screening, each participant was asked whether he had ever had asbestos exposure as an ironworker. Union records afforded the work status (active or inactive) as of the screening date. After screening, an industrial hygienist experienced in exposure assessment for epidemiological studies collected occupational exposure histories of 93 participants, chosen at random, to obtain more detailed exposure information on pulmonary toxicants.

Concern existed that work status could act as an intervening variable in any disease-exposure association, if acute exposure to welding fumes compromised the respiratory health of active workers, and inactive workers—consisting of mainly retired workers with the greatest number of years since joining union—experienced a rebound in respiratory health due to the removal of the acute exposure. Data analyses revealing poorer respiratory health among inactive subjects than active subjects across all measures of respiratory morbidity suggested that such a scenario was unlikely.

Comparison of Participants and Nonparticipants

Due to the low participation rate, data were collected to examine for differences between participants and nonparticipants. Union records provided the following information current to the date of cohort recruitment on all participants and nonparticipants: age, sex, race, years since joining union, and work status. In addition, a group of 140 nonparticipants matched to 140 randomly selected participants on age, sex, years in trade, years since joined union, and work status were targeted for telephone interview to obtain respiratory symptoms, smoking history, and occupational exposure history. The interviewer successfully reached and questioned 96 of these 140 nonparticipants.

Statistical Analyses

Statistical analyses were performed using SAS Version 6.03 [SAS Institute Inc., 1989a,b]. Differences between groups were analyzed using the chi-square test for categorical variables and the t-test for continuous variables. If subjects were matched, a paired t-test was used for continuous variables.

Simple and multivariate regression models were used to test the association between measures of respiratory morbidity and length of exposure. For continuous dependent variables, the untransformed dependent variable was used because it more closely approximated a normal distribution than the logarithm or square root of the variable. Logistic regression was used for dichotomous dependent variables. In multivariate regression, the independent variables were years since joining union, cigarette pack-years, their first-order interaction term, and age. Multivariate regression employed forward selection and a p value less than 0.05 to enter a term in the model. Years since joining union and pack-years were forced into the model. Mean values were subtracted from the component parts of the interaction term prior to multiplication to reduce collinearity. The component parts of the interaction term each had to have a p value less than 0.05 for the final model to include the interaction term.

RESULTS

Comparison of Participants and Nonparticipants

The 547 participants tended to be older than the 2,572 nonparticipants (mean age = 48.4 years among participants vs. 44.1 years among nonparticipants, $p < 0.001$). The two groups did not differ significantly with regard to sex or race. Participants had more years since joining the union (mean = 24.0 years vs. 17.7 years, $p < 0.001$) and were more likely to be active in the trade (78.8% vs. 61.8%, $p < 0.001$).

Among the 96 matched pairs of participants and nonparticipants, participants had significantly more asbestos exposure (Table I). The data did not confirm the purpoted high participation rate among asbestos-exposed ironworkers, as 87% of nonparticipants indicated some asbestos exposure. Participants reported a significantly higher prevalence of several respiratory symptoms. Participants did not diverge significantly from nonparticipants on cigarette pack-years, ever having welded, type of welding, material welded, ever having torch cut, use of respiratory protection, or assignment at a steel mill, foundry, coke oven, or powerhouse (data not shown).

Exposure Assessment

According to union records, the average length of time since joining the union was 24.5 years (range: 0.8–51.7 years). Calendar years in the trade spanned 1937–1990. Four hundred and thirty-one participants (78.8%) worked actively in the trade at screening. Five hundred and thirty-seven participants (98.2%) reported asbestos exposure.

Among the 93 participants with detailed occupational exposure histories, 96% reported asbestos exposure, and all reported welding and torch cutting (Table II). They performed arc, gas, MIG, and TIG welding and welded on structural steel, galvanized steel, stainless steel, and aluminum. The average ironworker had the longest exposure to fumes and gases from welding and torch cutting, followed by asbestos, air contaminants at steel mills, and air contaminants at foundries. Less than 10% of those interviewed reported wearing respiratory protection most of the time.

TABLE I. Comparison of Matched Participant and Nonparticipant Ironworkers, Local 25, Michigan 1989

	Participants (%) (N = 96)	Nonparticipants (%) (N = 96)	p value
Asbestos exposure			
Any	100	87	<0.001
Installed	30	15	0.018
Removed	79	63	0.019
Bystander, installation	57	46	NS[a]
Bystander, removal	66	35	<0.001
Fire blanket	94	83	0.018
Symptoms			
Chronic cough	35	25	NS
Chronic phlegm	47	30	0.016
Chronic bronchitis	33	17	0.008
Wheezing	29	17	0.039
Dyspnea, grade I	35	27	NS
Dyspnea, grade II	13	4	0.037
Dyspnea, grade III	13	4	0.037
Dyspnea, grade IV	10	8	NS
Dyspnea, grade V	8	10	NS

[a]Not significant, $p > 0.05$.

TABLE II. Cumulative Exposure to Pulmonary Toxicants Ascertained in a Subset of 93 Ironworkers Queried in Detail

Welding (mean and range, years)[a]	5.7 (0.1–20.8)
Type of welding[b]	
Arc (%)	100
Gas (%)	55
MIG (%)	50
TIG (%)	18
Material welded[b]	
Structural steel (%)	100
Galvanized steel (%)	99
Stainless steel (%)	79
Aluminum (%)	42
Torch cutting (mean and range, years)	4.9 (0.2–24.2)
Asbestos	
Installed (mean and range, years)	0.2 (0–3.5)
Removed (mean and range, years)	0.6 (0–6.5)
Bystander, installation (mean and range, years)	0.5 (0–5.0)
Bystander, removal (mean and range, years)	0.4 (0–1.6)
Steel mill (mean and range, years)[c]	2.1 (0–30)
Foundry (mean and range, years)[c]	1.8 (0–11)
Coke oven (mean and range, years)[c]	0.8 (0–9)
Powerhouse (mean and range, years)[c]	0.3 (0–3)
Pulp and paper mill (mean and range, years)[c]	0.04 (0–2)

[a]In this table years were prorated to account for part-time exposure (e.g., 2 hrs total per 8-hr shift) and seasonal exposure (e.g., 3 months per year).
[b]Percent of ironworkers who reported ever performing the activity.
[c]Total years at these worksites during which ironworker had high exposure to respiratory toxins (not including asbestos, welding fumes, or torch cutting fumes).

Workers who used such equipment tended to employ simple dust masks, which would have allowed penetration of fumes, gases, and asbestos fibers.

Respiratory Findings

Thirty-eight ironworkers (7.5% of the participants) had small irregular opacities with profusion of 1/0 or greater. Bilateral opacities (6.6%) accounted for more of the parenchymal abnormalities than did unilateral opacities (0.9%). In all cases the opacities occurred in the lower lung zones, and in half of the cases they extended to the middle or upper lung zones. None of the subjects exhibited rounded opacities. Some pleural abnormality was found in 105 participants (20.7%). One hundred and fourteen ironworkers (21.3%) had pleural thickening, 100 (18.7%) had pleural plaques, and 7 (1.3%) had pleural calcification. Pleural changes were divided about evenly between unilateral and bilateral abnormalities.

The mean (SD) percent predicted values for lung function were 98.7 (14.3) for FVC, 104.1 (18.9) for FEV_1, 103.6 (12.1) for FEV_1/FVC, and 90.7 (35.0) for FEF_{25-75}. Thirty-three subjects (6.0%) had reduced FVC, 36 subjects (6.6%) had reduced FEV_1, 35 subjects (6.4%) had reduced FEV_1/FVC, and 46 subjects (8.4%) had reduced FEF_{25-75}. The proportion with reduced values significantly exceeded ($p <$ 0.05) that of the reference population for FEF_{25-75} but not for FVC, FEV_1, or FEV_1/FVC.

On the physical exam, 46 participants (8.5%) presented bilateral rales, and 31 (5.7%) presented unilateral rales. None of the subjects showed finger clubbing. One hundred and forty-seven participants (28.5%) reported chronic cough, 180 (34.5%) reported chronic phlegm, 126 (24.0%) reported chronic bronchitis, and 112 (21.4%) reported wheezing. The number indicating shortness of breath was 197 (36.6%) at grade I, 63 (11.8%) at grade II, 62 (11.5%) at grade III, 55 (10.2%) at grade IV, and 69 (12.8%) at grade V. The study group exhibited significant increases in several respiratory symptoms compared with the reference population (Table III).

Relationship of Respiratory Findings to Ironwork

In the simple regression, radiographic abnormalities, rales, percent predicted pulmonary function except FEV_1/FVC, reduced pulmonary function, and all grades of dyspnea were significantly associated with years since joining

TABLE III. Distribution of Respiratory Symptoms Among 547 Ironworkers Participating in a Screening in Michigan 1989–1990 and in a Referent Population

	Nonsmokers			Ex-smokers			Smokers		
	Study group (N = 137) (%)	Referents[a] (N = 93) (%)	p value	Study group (N = 215) (%)	Referents[a] (N = 91) (%)	p value	Study group (N = 186) (%)	Referents[a] (N = 206) (%)	p value
Chronic cough	12.9	8.6	NS[b]	20.9	8.8	0.010	44.1	21.8	<0.001
Chronic phlegm	21.0	8.6	0.011	24.7	12.2	0.014	46.0	19.1	<0.001
Chronic bronchitis	12.9	3.2	0.010	14.8	8.8	NS	36.4	6.8	<0.001
Wheezing	9.0	1.1	0.017	17.9	7.7	0.019	27.7	9.7	<0.001
Dyspnea, grade I	26.2	9.7	0.002	33.3	33.0	NS	33.3	29.3	NS
Dyspnea, grade II	5.8	2.2	NS	5.6	7.7	NS	9.9	8.8	NS
Dyspnea, grade III	3.9	0.0	NS	6.8	3.3	NS	10.6	2.9	0.002

[a]Data for white males only [Petersen and Castellan, 1984].
[b]Not significant, $p > 0.05$.

the union (Table IV). Chronic cough, chronic phlegm, chronic bronchitis, and wheezing were not associated with years since joining the union.

In multiple regression profusion, pleural thickening, pleural plaques, rales, percent predicted FVC, reduced FVC, reduced FEV_1, reduced FEV_1/FVC, and dyspnea grades I, II, III, and IV remained significantly associated with years since joining the union (Table V). Profusion, rales, percent predicted pulmonary function, reduced pulmonary function, and each of the respiratory symptoms were significantly associated with cigarette pack-years. Only profusion and rales were significantly associated with the interaction term.

DISCUSSION

The level of respiratory morbidity in the study group resembled the level in the ironworkers examined by Fischbein et al. [1991]. Fischbein et al. found 7.2% of ironworkers with small opacities and 38.3% with pleural abnormalities, compared with 7.5% with small opacities and 21% with pleural abnormalities in the Michigan group. They reported spirometric abnormality in 7.6% of the workers for FVC and 47.6% for FEF_{25-75} using conventional criteria for "abnormal" [Miller et al., 1980]. Applying these same criteria, the percentages of the Michigan subjects with abnormality were 8.0% for FVC and 36.9% for FEF_{25-75}. Fischbein et al. tallied 11% with rales, 44.1% with shortness of breath, and 19.6% with chronic bronchitis. The present study found 14.2% with rales, 36.6% with shortness of breath, and 24.0% with chronic bronchitis.

However, the current study identified only 2.1% of its subjects as having "abnormal" FEV_1/FVC vs. 36.0% in the Fischbein et al. study. The gap in the percentage of cigarette smokers, 74.6% in the present study and 79.3% in the Fischbein et al. study, was not wide enough to explain this discrepancy. Neither age, years in trade, nor years since joining union differed greatly between the two investigations. Perhaps a greater proportion of asthmatics in the New York cohort or more pack-years among tobacco users, variables for which Fischbein et al. did not provide data, could account for the dissimilarity in FEV_1/FVC.

The 7.5% prevalence of small irregular opacities in the study group exceeded the background prevalence. Castellan et al. [1985] found 0.07% with such opacities among nonexposed blue collar workers; Kilburn et al. [1986] reported 0.5% for a random sample of the Michigan population. The 8% prevalence of bilateral pleural plaques surpassed the background prevalence of 1% found by Hillerdal [1978]. The screened workers had an increased prevalence of reduced FEF_{25-75}, when compared with the reference population of Miller et al. [1980], and an increased prevalence of respiratory symptoms when compared with the reference population of Petersen and Castellan [1984]. The 12.8% of subjects with grade V dyspnea greatly exceeded the 1% found by Fletcher et al. [1959] in male postal workers, but did not seem remarkable for asbestos-exposed workers, since Demers et al. [1990] revealed a 20.0% prevalence of grade V dyspnea among asbestos-exposed boilermakers. The 8.5% prevalence of bilateral rales exceeded the 3% prevalence of rales reported by Murphy et al. [1978] for unexposed workers.

Dissimilarities in demographic and exposure variables between the main contrasted groups were controlled for in the data analysis (age for predicted pulmonary function and tobacco use) or were present at a level that would not introduce major spurious differences in the health variables. The mean age for our study participants was 48.9 years

TABLE IV. Simple Regression of Respiratory Morbidity Indices Against Years Since Joining the Union Among 547 Ironworkers, Michigan 1989–1990

	Years since joining union	
Dependent variable	Coefficient (SE)	p value
Profusion	0.019 (0.003)	<0.001
Pleural thickening	0.082 (0.012)	<0.001
Pleural plaques	0.081 (0.012)	<0.001
Pleural calcification	0.114 (0.042)	0.007
Rales	0.058 (0.013)	<0.001
FVC, % predicted	−0.350 (0.062)	<0.001
FEV_1, % predicted	−0.305 (0.083)	<0.001
FEV_1/FVC, % predicted	−0.096 (0.053)	NS[a]
FEF_{25-75}, % predicted	−0.501 (0.152)	0.001
FVC, reduced	0.077 (0.019)	<0.001
FEV_1, reduced	0.070 (0.018)	<0.001
FEV_1/FVC, reduced	0.055 (0.018)	0.002
FEF_{25-75}, reduced	0.046 (0.015)	0.003
Chronic cough	0.003 (0.010)	NS
Chronic phlegm	0.008 (0.009)	NS
Chronic bronchitis	0.007 (0.010)	NS
Wheezing	0.013 (0.010)	NS
Dyspnea, grade I	0.047 (0.009)	<0.001
Dyspnea, grade II	0.082 (0.015)	<0.001
Dyspnea, grade III	0.081 (0.015)	<0.001
Dyspnea, grade IV	0.071 (0.015)	<0.001
Dyspnea, grade V	0.067 (0.014)	<0.001

[a]Not significant, p > 0.05.

compared with 33.5 years for Petersen and Castellan. Miller et al. and Petersen and Castellan excluded subjects with a prior history of respiratory disease, but our study did not. All three groups consisted of essentially white males only.

Our study confirmed the Fischbein et al. findings in multiple regression of exposure length's association with parenchymal and pleural radiographic abnormalities, rales, percent predicted FVC, and shortness of breath. Neither investigation produced an association with percent predicted FEV_1/FVC or chronic bronchitis. Fischbein et al. indicated an association with percent predicted FEF_{25-75} that we did not find, maybe due to differences in the set of independent variables used in the regression procedure.

Among the pulmonary toxicant exposures of ironworkers, only asbestos causes the spectrum of abnormalities discovered in the study group. Asbestos has been shown to cause small irregular opacities on chest X-rays, pleural abnormalities, decreased pulmonary function, rales, and respiratory symptoms [Browne, 1994; Rom, 1992]. Welding in the absence of asbestos exposure does not produce rales or small irregular opacities on chest X-ray [Waldron, 1994]. Silica ordinarily produces small irregular opacities in the upper lung zones [Weill et al., 1994; Balaan and Banks, 1992], and coal dust produces rounded opacities [Parkes, 1994; Attfield and Wagner, 1992], whereas the ironworkers had small irregular opacities in the lower lung zones and no rounded opacities.

Nonetheless, non-asbestos exposures may have contributed to the morbidity. Welding has been linked to deficits in FVC [Akbarkhanzadeh, 1980] and FEV_1 [Chinn et al., 1990; Akbarkhanzadeh, 1980; Barhad et al., 1975], as well as increased dyspnea [Chinn et al., 1990; Barhad et al., 1975; Oxhoj et al., 1979]. Cigarette smoking has been shown to cause chronic bronchitis, emphysema, respiratory symptoms [U.S. Surgeon General's Advisory Committee on Smoking and Health, 1979], and reductions in pulmonary function, especially FEV_1 [Miller et al., 1983; Seltzer et al., 1974]. Indeed, our study found pack-years to be associated with profusion, rales, all PFT variables, and all respiratory symptoms. Our findings of interaction between cigarette smoking and asbestos have been noted previously in the production of parenchymal opacities [Blanc et al., 1988; Kilburn et al., 1986] and rales [Blanc et al., 1988].

Extrapolating from the percent of matched participants and nonparticipants claiming asbestos exposure, about 20% of the subset of ironworkers with asbestos exposure participated in the screening. In light of this low participation rate, the higher prevalence of respiratory symptoms among participants vs. nonparticipants causes concern that ironworkers may have decided to volunteer based on the presence of respiratory symptoms. Such self-selection could have inflated the study group's prevalence of respiratory symptoms as well as other pulmonary indices because the respiratory measures were highly intercorrelated.

On the other hand, the higher prevalence of respiratory symptoms among participants may simply reflect the higher asbestos exposure among participants. Furthermore, even if the subjects with opacities constituted all such workers from the population, the resulting prevalence of 1.5% for the population would still remain above the background prevalence.

Exposure histories revealed that the measures of exposure length included not only asbestos exposure but also considerable exposure to welding fumes and other respiratory toxicants. An alternate study design that would have extracted substance-specific exposure lengths from all participants may not have identified the etiology more effectively than the current exposure assessment. Subjects in the exposure assessment survey frequently commented that it was difficult to assert asbestos exposure since employers did not label asbestos or otherwise inform them that insulation of fireproofing contained asbestos. Respondents could not separate exposures to various pulmonary toxins at a worksite (for example, metal dust and fumes, coke, silica, and fluorides at a steel mill).

TABLE V. Multiple Regression of Respiratory Morbidity Indices Against Years Since Joining the Union and Cigarette Pack-Years Among 547 Ironworkers, Michigan 1989–1990

	Years since joining union		Cigarette pack-years	
Dependent variable	**Coefficient (SE)**	**p value**	**Coefficient (SE)**	**p value**
Profusion[a]	0.014 (0.003)	<0.001	0.004 (0.001)	0.002
Pleural thickening[b]	0.043 (0.022)	0.049	0.005 (0.004)	NS[c]
Pleural plaques	0.080 (0.013)	<0.001	0.006 (0.004)	NS
Pleural calcification[b]	−0.022 (0.053)	NS	−0.002 (0.012)	NS
Rales[a]	0.049 (0.014)	<0.001	0.022 (0.005)	<0.001
FVC, % predicted	−0.255 (0.063)	<0.001	−0.112 (0.025)	<0.001
FEV_1, % predicted	−0.107 (0.081)	NS	−0.247 (0.032)	<0.001
FEV_1/FVC, % predicted	0.013 (0.053)	NS	−0.144 (0.021)	<0.001
FEF_{25-75}, % predicted	−0.063 (0.151)	NS	−0.485 (0.061)	<0.001
FVC, reduced	0.058 (0.021)	0.006	0.022 (0.006)	<0.001
FEV_1, reduced	0.058 (0.021)	0.004	0.022 (0.005)	<0.001
FEV_1/FVC, reduced	0.046 (0.021)	0.026	0.021 (0.006)	<0.001
FEF_{25-75}, reduced	0.031 (0.018)	NS	0.027 (0.005)	<0.001
Chronic cough	−0.012 (0.011)	NS	0.019 (0.004)	<0.001
Chronic phlegm	−0.001 (0.010)	NS	0.014 (0.004)	<0.001
Chronic bronchitis	−0.006 (0.011)	NS	0.018 (0.004)	<0.001
Wheezing	0.003 (0.012)	NS	0.014 (0.004)	<0.001
Dyspnea, grade I	0.041 (0.010)	<0.001	0.017 (0.004)	<0.001
Dyspnea, grade II	0.078 (0.016)	<0.001	0.016 (0.005)	<0.001
Dyspnea, grade III	0.077 (0.017)	<0.001	0.018 (0.005)	<0.001
Dyspnea, grade IV	0.066 (0.017)	<0.001	0.016 (0.005)	0.001
Dyspnea, grade V[b]	0.019 (0.025)	NS	0.021 (0.005)	<0.001

[a]Final model included interaction term.
[b]Final model included age.
[c]Not significant, $p > 0.05$.

In conclusion, the screened ironworkers exhibited an increased prevalence of respiratory morbidity as evidenced by chest X-ray, pulmonary function test, physical examination, and medical questionnaire. Many of the respiratory morbidity indices were associated with years since joining the union, even after controlling for cigarette pack-years and age. Imprecision in the exposure measure did not allow quantification of the relative contribution of asbestos, cigarette smoking, and welding and torch cutting to the respiratory morbidity. The results reemphasize the need for proper work practices and personal protective equipment when handling asbestos. Smoking cessation programs and use of fume respirators during welding and torch cutting may also help lower respiratory morbidity in this trade.

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