Respiratory Diseases Among Union Carpenters: Cohort and Case-Control Analyses

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Lung diseases, defined by ICD-9 diagnoses on medical insurance claims, were studied through the combined use of administrative records, private health insurance, and workers' compensation claims for a cohort of 10,938 active union carpenters between 1989 and 1992. The cohort defined the study base for a nested case-control study, in which cases (n = 220) were initially identified by an ICD-9 code for asthma in private health insurance or workers' compensation files. A questionnaire was used to collect information on respiratory history and potential home and workplace exposures. Questions used by Burney et al. to define a discriminant function predictor (DFP) of a bronchial response to histamine were used to reclassify cases and controls for further exploratory analyses.

Bronchitis accounted for over 50% of the lung disease cases among this cohort followed by asthma, chronic obstructive airway disease, and chronic bronchitis. Incidence density rates of asthma, chronic bronchitis, and chronic obstructive airway disease adjusted for age, sex, and time in the union increased with increasing age. Using Surveillance, Epidemiology, and End Results (SEER) Program data to estimate expected lung cancer cases in our cohort, an elevated standardized incidence rate (SIR) was seen among male carpenters between the ages of 45–54. Smoking history was not available for the entire cohort.

Using the ICD-9 or Burney case definition of asthma, odds ratios were significantly elevated for exposure to hay, epoxy paints, enzymes, animals, and molds. Additional exposures associated with asthma using Burney's definition, are ones to which a majority of these carpenters were exposed including cement, drywall, and demolition dusts. Am. J. Ind. Med. 33: 131–150, 1998. *© 1998 Wiley-Liss, Inc.*

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INTRODUCTION

Carpenters may be exposed to a number of substances which may place them at increased risk for lung disorders. Exposures include dusts such as silica, asbestos, wood, cement, dusts from drywall finishing and other mineral dusts. These workers are also exposed to man-made mineral fibers, solvents, paints, coatings, glues, fillers, and cutting and welding fumes. Workers involved with renovation may have exposures to molds, dust mites, and other organic dusts. Exposures of painters, welders, sheet metal workers, insulators, and sawmill workers, which have been reported to be associated with lung disease, are of potential importance to union carpenters due to the diverse nature of their work and the possibility of exposures while working in close proximity to these trades. Construction workers may also have occupational exposures, not commonly associated with construction, which may be present in industries in which they are working on construction [Courteau et al., 1994].

There are relatively few epidemiologic data on morbidity from lung diseases among carpenters. Surveillance data

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document increased lung disease risks among construction workers, second only to manufacturing [NIOSH, 1991]. Industries such as ship and boat building and repair, which employ carpenters and other construction crafts, had the highest rate of reported occupational dust diseases of the lung in 1990 (33.5 cases per 10,000 full-time workers) [NIOSH, 1992].

Excess deaths due to lung cancer have consistently been reported among carpenters [NIOSH, 1974; Firth et al., 1993; Zahm et al., 1989; Stellman and Garfinkel, 1984] and among construction workers in general [Robinson et al., 1995a,b] with the excess typically attributed, in part, to asbestos. The increased prevalence of asbestos-related pleural abnormalities has been reported to be increased among carpenters. [Garcia-Closas and Christiani, 1995; Fischbein et al., 1993]. Analyses of multiple cause of death listings show the construction industry to be one of the industries most frequently listed for deaths mentioning asbestosis, malignant neoplasms of the pleura, coal workers' pneumoconiosis and silicosis [NIOSH, 1992, 1996].

Asthma and more nonspecific lung diseases are reported to be associated with various construction trades [Heederik et al., 1990, Wang et al., 1994; White and Baker, 1988; Hunting and Welch, 1994; Weislander et al., 1994; Norrish et al., 1992; Ng et al., 1994]. Increased mortality due to asthma has been demonstrated among carpenters in California [Department of Health and Human Welfare, 1980; Schencker et al., 1993].

Increased bronchial hyperresponsiveness has been described among painters compared to referents. Young painters exposed to water-based paints have been observed to have decreased FEV_1 and FVC during the workday [Weislander et al., 1994]. Cases of occupational asthma have been reported to be caused by toluene di-isocyanate (TDI) prepolymer in wood varnish [Vandenplus et al., 1992], and an increased prevalence of asthma has been observed in workers spraying paints containing mixed isocyanates [Seguin et al., 1987].

Exposure to a number of wood dusts has been associated with diagnoses of asthma [Norrish et al., 1992], most commonly red cedar [Chan-Yeung, 1990; Siracusa et al., 1995], but also eastern white cedar [Malo et al., 1994], oak [Malo et al., 1995], and possibly pine and spruce [Hessel et al., 1995]. Children living in homes in Denmark with ''much particle board'' were observed to be at risk for asthma [Daugbjerg, 1989].

With no single comprehensive database available for the study of occupational disorders and injuries, a number of avenues have been explored including the use of administrative data such as workers' compensation files [Mathias et al., 1990; Franklin et al., 1991; Tanaka et al., 1988] and health insurance claims [Bernacki and Tsai, 1986; Bernacki et al., 1989; Van Peenen et al., 1986; Blose and Holder, 1991; Pell and Fayerweather, 1985; Pell, 1989; Bond, 1983]. In using health insurance claims data, it cannot be assumed that all cases of work-related lung disease will be recognized in workers' compensation files. Physicians typically receive little training in the recognition of diseases associated with occupation. The British Surveillance of Work-Related and Occupational Respiratory Disease (SWORD) Project estimated that the frequency of occupational asthma in the U.K. may be three times greater than reported even with their increased surveillance endeavors [Meredith et al., 1991]. Blessman [1991] has described claims for occupational disease as being more likely to be rejected for workers' compensation coverage than ones for occupational injury. He conjectures that long latency between exposure and disease; multiple causes of disease, some of which are nonoccupational; difficulty associating disease with employment at a specific place; and difficulty in quantifying exposures may contribute to the problem of under-reporting of occupational disease to workers' compensation. Occupational exposures may contribute to many, but not all or even most, cases of common lung disorders with multifactorial etiologies, (e.g., asthma, chronic obstructive airway disease). In such cases, work-relatedness may often be overlooked, making the utility of workers' compensation data alone equivocal.

Practical problems that make the study of construction workers difficult including frequently changing employers, irregular and temporary employment, and often small and dispersed work sites make the use of existing data sources particularly appealing for this group of workers. The major objective of this project was to integrate several existing databases to identify a cohort of union carpenters and to provide a more complete picture of the incidence and prevalence of lung diseases of possible occupational origin among these workers. The cohort defined a study base for a nested case-control study designed to identify possible etiologic associations between specific occupational exposures and asthma among carpenters.

MATERIALS AND METHODS

Databases and Cohort Definition

Databases used included: a) health insurance eligibility files from the Carpenters Trusts of Western Washington (CTWW), b) union membership files of the United Brotherhood of Carpenters and Joiners (UBC), c) medical insurance claims files from the CTWW, and d) workers' compensation data from the Washington State Department of Labor and Industries (L&I). Data were linked on an individual basis to establish a cohort of workers, to define the types of carpentry work done by the cohort and their periods of risk, and to measure the occurrence of lung diseases among this defined carpenter population. Data were abstracted from each source for the period January 1, 1989, through December 31, 1992. The individual data sources are described below.

The CTWW provides medical insurance coverage for members of the UBC in Washington State. Eligibility for medical insurance is based on working a required number of union hours each quarter. The CTWW maintains data for each individual who works union hours in the State of Washington. In addition to demographic data (date of birth, sex, and current Washington State UBC local), the number of hours worked for each calendar month and a variable which indicates each month in which the member is eligible for medical insurance coverage are recorded. For purposes of our analyses, the 18 union locals in Western Washington were grouped into categories based on the predominant type of carpentry work of the local with the assistance of the Carpenters' Health and Safety Fund District Environmental Coordinator in Washington State.

The UBC national membership files contain demographic information (date of birth, sex), membership status, current union local affiliation, initiation date into the union, and historical data concerning union activity. The national membership files were used to identify the Washington State UBC local for the period, 1989 to 1992, for those persons who were no longer union members or who were no longer working in Washington State at the time of data abstraction for this study and to provide information missing from CTWW files.

Computerized medical claims data were available through CTWW. All records were abstracted which had a primary ICD-9 code for a list of lung diseases of interest. All file data elements were abstracted for each claim (line item) including age, sex, date of service on claim, and primary and secondary ICD-9 diagnosis codes.

As one of the few state-administered funds, Washington State workers' compensation claims records include the ICD-9 codes and treatment codes for medical claims covered under workers' compensation. These data were made available through collaboration with the Safety and Health Assessment & Research Program (SHARP), Department of Labor and Industries.

Data Linkage

The CTWW generated a computer file containing name, social security number, date of birth, and a unique identifier assigned to each carpenter covered by the trust at any time from 1989 to 1992. This list was provided to the National UBC office and the Washington State Department of Labor and Industries for abstraction of relevant data on these individuals. The matching algorithm required the combination of two identifiers (social security number plus last name or date of birth). Data were provided from all sources with the unique identifier to allow linkage of all data on an individual basis. Names and addresses of cases and controls were later provided by the union. These data sources do not provide information on race.

Carpenter Cohort and Case Definitions

Using the health insurance eligibility files, an historical cohort of carpenters who worked at least 3 months of union time between 1989 and 1992 was identified. No restriction was placed on a minimum number of hours of work per month and the 3 months did not have to be consecutive. The cohort was dynamic with both entrances and exits allowed over the 4-year period. Malignant and nonmalignant respiratory conditions were studied with case definitions based on ICD-9 diagnosis codes attached to medical claims.

Analyses of Incidence and Prevalence of Lung Disorders

Descriptive analyses of respiratory disease claim rates. Cases of each target lung disorder were identified using medical claims from both workers' compensation data and health insurance data. Crude incidence density rates were calculated for each of the lung diseases for which we had claims data. Incidence density was defined as the number of incident cases of each lung disease, defined by three digit ICD-9 codes, per 1,000 months of insurance eligibility. An incident case was defined the first time a diagnosis was made for each individual in this 4-year, follow-up period. The event had to have occurred in a month in which the individual had insurance eligibility to be counted. While it is recognized that the definition of an ''incident'' case for this study would include prevalent and incident cases for chronic diseases, such as asthma, the definition chosen was considered useful for internal comparisons.

Internal Comparisons by Stratification and Poisson Regression

For internal comparisons, incidence density rates and crude rate ratios were calculated for each lung disorder for which there were greater than 50 cases observed during this 4-year period of observation. The diagnoses analyzed included bronchitis, asthma, chronic bronchitis, and chronic obstructive airway disease. Person-months of insurance eligibility and the number of cases were stratified by age, sex, time in the union, and predominant type of carpentry work. Age and time in the union were treated as time varying variables with person-time and events appropriately distributed as these variables changed over the 48-month follow-up period. Person-time at risk stopped accumulating at the time a person first became a case. Adjusted rate ratios were calculated for each of these disorders using Poisson regression [Kleinbaum et al., 1988]. Deviation from the mean coding was used for the predominant type of carpentry to allow comparisons to an overall group mean since no *a priori* low risk group was identified [Lemeshow and Hosmer, 1984].

External Comparisons

Data from the National Health Interview Survey (NHIS) Occupational Supplement [U.S. Dept. Health and Human Services, 1993, 1994], and Surveillance, Epidemiology, and End Results (SEER) Program [Ries et al., 1994] were used for purposes of external comparison.

Comparisons to the 1988 National Health Interview Survey, Occupational Health Supplement. The National Health Interview Survey (NHIS) is a household survey designed to provide estimates representative of the U.S. civilian noninstitutionalized population [U.S. Dept. of Health and Human Services, 1994]. One adult (aged 18 years or over) in each sampled household was selected at random to be interviewed with the NHIS Occupational Health Supplement 1988 questionnaire. Currently employed persons, 18 years of age and over, were asked if they had certain health conditions during the past 12 months, including asthma and chronic bronchitis. These estimates thus represent 12-month period prevalence rates for these conditions based on self-reports. The only respiratory diseases for which information was available from the NHIS Occupational Supplement were asthma and chronic bronchitis.

For the purpose of comparing these carpenters with the NHIS Occupational Health Supplement data, 12-month period prevalences were estimated. Within each age and sex category, the first claim filed for asthma or chronic bronchitis by each carpenter was identified each year. Person-months of insurance eligibility, converted to person-years of observation, were calculated for each year and then summed for the 4 years. Twelve-month period prevalence rates were calculated for each disorder defined as number of cases divided by person-years of observation for age and sex specific groups. Due to the small number of individuals younger than 18 years of age or older than 69 years of age in our cohort, these individuals were not included in our comparisons. Comparison age and sex specific period prevalence were generated from original data with appropriate weights provided on CD-ROM by NCHS using provided age groups [U.S. Dept. of Health and Human Services, 1994].

Analyses of Lung Cancer Incidence and Comparisons to Surveillance, Epidemiology, and End Results (SEER) Program. A continuing project of the National Cancer Institute, the SEER Program collects cancer data on a routine basis from designated population-based cancer registries in areas of the country selected primarily for their ability to operate and maintain a population-based cancer reporting system and for their epidemiologically significant population subgroups. With respect to selected demographic and epidemiologic factors, they are reasonably representative subsets of the U.S. population. National trends in cancer incidence are derived from this database. The yearly cancer incidence rate is the number of new cancers of a specific site/type occurring in a specified population during a year, expressed as the number of cancers per 100,000 people. Cancer of the lung and bronchus, for our comparisons, included ICD-9 codes 162.2–162.99 [Ries et al., 1994].

Standardized Incidence Ratio analyses (indirect adjustment) were used to compare observed cases of cancer of the lung and bronchus among these carpenters to the expected number of cases based on SEER data 1990 to 1991. All claims filed for cancer of the lung or bronchus were identified among the carpenters cohort. No cases of cancer were identified among the 222 women in this cohort and therefore the analyses were limited to men. Person-months of insurance eligibility were stratified by age categories used in the SEER summary data and were then converted to person-years of observation over this 4-year time period. Person-time at risk stopped accumulating after the person became a case. National SEER incidence rates were used to calculate expected incident lung cancer cases as these were essentially the same as those for the State of Washington. SEER rates were applied to the cohort person-years by age and sex to calculate expected numbers of cases. These expected cases were compared to observed cases for each age category (standardized incidence ratio = observed/expected). The overall standardized incidence ratio and approximate 95% confidence limits were then calculated for the entire population [Checkoway et al., 1989].

Some of the lung cancer claims in our data could have resulted from treatment of prevalent rather than incident cases. To more closely approximate incidence, the same analyses were performed after discounting the first 3 months of person-time observed for each member of the cohort. This ignored both person-time and cases that occurred in the first three months of eligibility which we were able to observe, making the assumption that it would be unlikely for an individual diagnosed with lung cancer to go longer than 3 months without medical care.

Case-Control Study of Asthma

Selection of cases and controls. A nested case-control study of asthma was conducted among the cohort of carpenters. Asthma cases were identified by a primary ICD-9 code of 493 attached to a claim for medical care from either workers' compensation or private health insurance records. Individuals who were known to be dead at the time of sampling were omitted from the cohort (n = 78). Among this restricted cohort, 220 individuals filed claims for asthma during 1989–1992. The ‘‘diagnosis date’’ was assigned as the date of the first claim filed for asthma. Controls were matched by sex and age, plus or minus 2 years, at the time of the diagnosis of the case. Individuals must have already entered the cohort, as marked by a month of hours worked, when the case was diagnosed in order to serve as a control for that case. After appropriate matching criteria were met, two controls were selected randomly for each case with individuals allowed to serve as a control for more than one case.

Asthma Symptoms and Exposure History Questionnaire

A questionnaire soliciting information on respiratory symptoms, occupational history, occupational exposures to specific substances, and lifestyle factors was developed. The respiratory symptom questions were adopted from the American Thoracic Society (ATS) DLD-78 questionnaire with modifications used by the Agency for Toxic Substances and Disease Registry (ATSDR) for study of residents near hazardous waste sites [Ferris, 1978; ATSDR, 1993]. Additional refinements to the ATS symptom questionnaire proposed by Burney for assessment of asthma were included in the final questionnaire [Burney and Chin, 1987].

The occupational/environmental exposure questionnaire included questions concerning exposures to a wide variety of substances used in construction and substances known to be associated with asthma. The list of potential construction exposures was generated in a focus group of carpenters and through literature review. Chan-Yeung’s extensive review of agents associated with asthma [Chang-Yeung, 1990], as well as agents identified through the National Institute for Occupational Safety and Health Sentinel Event Notification System for Occupational Risks (SENSOR) program [Reilly et al., 1994], and the British SWORD project [Meredith et al., 1991] were also used in the process of identifying potentially relevant exposures. Subjects were queried about exposures they had experienced in the last 10 years.

The questionnaire was tested on three occasions with revisions made between tests. Cases and controls were contacted by mail and asked to complete the self-administered questionnaire. A total of three separate mailings occurred. In a final effort to enhance participation, each nonresponding carpenter was contacted by telephone by a member of the study team. The call was used to answer any questions the individuals might have about the study and to encourage their participation by completing the questionnaire in the same manner as the other respondents. No attempt was made to gather information over the phone.

Analyses of Case-Control Data

The initial analyses consisted of generation of descriptive data comparing cases and controls as well as respondents and nonrespondents to the mailed questionnaire. To assess the representativeness of the pool of individuals selected for the case-control study, Poisson regression analyses were used to compare the cases and controls to the entire cohort including age, sex, and time in the union as covariates. In addition to standard descriptive statistics for cases and controls, analyses included calculation of univariate crude odds ratios and confidence intervals based on ‘ever’ vs. ‘never’ exposure to substances at work as well as substances found in the home. Adjusted odds ratios were calculated using unconditional multiple logistic regression controlling for age, sex, and smoking [Checkoway et al., 1989; Pearce et al., 1988]. An unconditional logistic model was chosen in order to make maximum use of the questionnaire data completed by cases and controls.

Additional exploratory analyses were conducted utilizing symptom data from the respiratory questionnaire. Cases and controls were redefined based on items included in the respiratory symptom questionnaire by Burney et al. [1989] to define a discriminant function predictor of a bronchial response to histamine (in last 12 months one of following: wheeze, waking with attack of shortness of breath, and tightness in chest on contact with animals, feathers or dust; or intermittent or regular breathing problems). The analyses described above were repeated using this definition of an asthma case.

Statistical Management of Data

SAS Version 6.10 (SAS Institute) was used for descriptive analyses, crude rates, and data stratification. EGRET [Statistics and Epidemiology Research Corporation, 1991] was used for Poisson regression analyses. Data from the asthma case-control study were reviewed for accuracy and entered into a database using Epi Info [Dean et al., 1994]. The data were then converted to a SAS data file for statistical analyses using PC-SAS [SAS].

RESULTS

Description of the Cohort

From union eligibility files, 10,938 active union carpenters were identified who had worked at least 3 months between 1989 and 1992. Among the cohort, 10,628 (98%) were men and 222 (2%) were women. Their ages at entry into the cohort ranged from 15 to 76 years with a mean of 36 years and a median of 34 years. Mean age at entry into the cohort for men was 35.5 years and the median was 34 years. For women, the mean age at entry

TABLE I. Distribution of Cohort by Predominant Type of of Carpentry Work of the Union Local

Predominant Work of Local	N	%
Light commercial	2,831	25.6
Heavy commercial	3,922	35.9
Drywall	1,525	13.9
Millwrighting	190	1.7
Piledriving	602	5.5
Cabinet and fixture work	72	0.7
Residential	282	2.6
Lumber and sawmill	3	0.0
''Mixed'' tasks	960	8.8
Unknown	551	5.0

was 31 years and the median was 35 years. Time in the union at the time of entry into the cohort ranged from less than 1 year to 48 years with a mean of 6.2 years and a median of 1 year. The distribution of the cohort by predominant type of carpentry work of the union local with which each carpenter was affiliated is presented in Table I.

Over this 4-year period the cohort worked 39,000,692 union hours. The number of hours worked per individual ranged from 31 to 13,698 with a mean number of hours worked over this time period of 3,566 hours, or 892 hours worked per person per year. There was only one individual reporting over 11,000 hours. Omitting this individual does not change the mean hours worked per individual due to the size of the cohort. There were 117 individuals reporting over 8,500 hours. The number of months of insurance eligibility ranged from none to 48, with a mean and median of 27 months. Due to the dynamic nature of this cohort, with both entrances and exits over this four-year period, the mean values should not be assumed to be representative of mean hours worked or mean months of insurance coverage per year of these union carpenters.

Crude Incidence Density Rates

Incidence density rates of the lung diseases studied are presented in Table II. Bronchitis (ICD-9 490) accounted for over 50% of the lung disease cases among this cohort between 1989 and 1992. This was followed by asthma (ICD-9 493), chronic obstructive airway disease (ICD-9 496), and chronic bronchitis (ICD-9 491). The 931 cases of lung disease occurred among 812 different individuals. Nine cases of asbestosis were identified among this cohort. Ninety-four percent of all claims for lung disease occurred in the private health insurance files. Twenty-eight different individuals had respiratory medical claims in the workers' compensation files for seven different diagnoses. The diagnoses which occurred in workers' compensation files included bronchitis, chronic bronchitis, asthma, chronic obstructive airway disease, coal workers' pneumoconiosis, asbestosis, and respiratory conditions due to fumes.

TABLE II. Incidence Density Rates of Cases* of Selected Lung Diseases per 1,000 Months of Insurance Eligibility Among Union Carpenters in Washington State 1989–1992

ICD-9 code	(description)	N	% of lung diagnoses	Crude rate
039.1	(Actinomycosis)[a]	0	0	—
114	(Coccidiomycosis)	0	0	—
117.3	(Aspergillosis)[a]	1	0.1	0.004
162	(Neoplasm trachea, bronchus, lung)	13	1.4	0.046
163	(Neoplasm of pleura)	0	0	—
165	(Neoplasm, ill-defined respiratory)	1	0.1	0.004
239.1	(Unspecified respiratory neoplasm)[a]	9	1.0	0.032
490	(Bronchitis)	511	54.9	1.81
491	(Chronic bronchitis)	51	5.5	0.18
492	(Emphysema)	22	2.4	0.08
493	(Asthma)	213	22.9	0.76
494	(Bronchiectasis)	1	0.1	0.004
495	(Extrinsic allergic alveolitis)	0	0	—
496	(Chronic obstructive airway, NOC)	90	9.7	0.32
500	(Coal workers' pneumoconiosis)	1	0.1	0.004
501	(Asbestosis)	9	1.0	0.032
502	(Silicotic pneumoconiosis)	0	0	—
503	(Pneumoconiosis, other)	1	0.1	0.004
504	(Pneumonopathy, dust)	0	0	—
505	(Pneumoconiosis, unspecified)	1	0.1	0.004
506	(Respiratory cond. due to fumes/vapors)	6	0.6	0.021
508	(Respiratory, unspecified extrinsic agent)	1	0.1	0.004
TOTAL		931		

*Uses only the first time each diagnosis was made for each individual and includes all person months of insurance eligibility in denominators.
[a]Only disorders for which the ICD-9 code was used beyond a three digit level.

Internal Comparisons

Stratified crude rates, crude rate ratios, and adjusted rate ratios. In Tables III–VI, the distribution of cases stratified by age, sex, time in the union, and predominant type of carpentry work, crude rates and rate ratios, and adjusted rate ratios are presented for asthma, bronchitis, chronic bronchitis, and chronic obstructive airway disease. Due to the limited number of individuals (n = 3) whose local did predominantly lumber or sawmill work, these individuals were omitted from further analyses. The data were too sparse to include the predominant type of carpentry work in

TABLE III. Crude Rates, Crude Rate Ratios, and Adjusted Rate Ratios for Internal Comparisons of Rates of Lung Diseases Among Union Carpenters Washington State 1989–1992: Asthma (ICD-9 493)*

Covariate	# Cases	Months of coverage	Crude Rate[a]	Crude RR	Adjusted RR[b] 95% CI
Age					
<30 years	33	54,397	0.61	1	1
30–44 years	112	146,116	0.77	1.3	1.6 (1.0, 2.4)
45–60 years	55	61,463	0.90	1.5	2.0 (1.2, 3.4)
60+ years	13	14,465	0.90	1.5	2.2 (1.1, 4.5)
Sex					
Males	207	272,087	0.76	1	1
Females	6	4,396	1.4	1.8	1.7 (0.68, 4.1)
Time in the union					
Up to 1 years	50	51,289	0.98	1	1
1–10 years	66	89,891	0.73	0.75	0.70 (0.48, 1.0)
>10 years	82	110,491	0.74	0.76	0.59 (0.40, 0.87)
			Rate (95% CI)[d]		Unadjusted RR[b]
Predominant work[c]					
Light commercial	61	72,670	0.84 (0.65, 1.1)		1.1
Heavy commercial	78	106,598	0.73 (0.58, 0.91)		0.94
Drywall	30	41,308	0.73 (0.49, 1.0)		0.94
Millwrights	2	4,698	0.43 (0.05, 1.6)		0.55
Piledrivers	7	17,535	0.40 (0.16, 0.82)		0.51
Cabinet/fixture	0	2,102	—	—	—
Residential	5	3,709	1.3 (0.42, 3.0)		1.7
Mixed	23	24,117	0.95 (0.60, 1.4)		1.2

*Person-time at risk stopped accumulating after individual became a case. Uses first claim in an eligible month.
[a]Rate per 1,000 months of insurance coverage.
[b]Predominant task not included in model; adjustment for age, sex, and time in the union.
[c]RR = rate compared to overall group rate of 0.78 (0.68, 0.90).
[d]Poisson 95% CI.

TABLE IV. Crude Rates, Crude Rate Ratios, and Adjusted Rate Ratios for Internal Comparisons of Rates of Lung Diseases Among Union Carpenters Washington State 1989–1992: Bronchitis (ICD-9 490)*

Covariate	# Cases	Months of coverage	Crude rate[a]	Crude RR	Adjusted RR 95% CI
Age					
<25 years	20	18,778	1.1	1	1
25–34 years	166	87,255	1.9	1.8	1.8 (1.1, 3.1)
35–44 years	187	90,829	2.1	1.9	2.1 (1.2, 3.5)
45–54 years	78	44,408	1.8	1.7	1.8 (1.0, 3.2)
55–64 years	54	27,559	2.0	1.8	2.1 (1.2, 3.8)
65+ years	6	2,432	2.5	2.3	2.8 (1.1, 7.3)
Sex					
Males	502	266,865	1.9	1	1
Females	9	4,438	2.0	1.1	0.65 (0.27, 1.6)
Time in the union					
Up to 1 years	97	50,874	1.9	1	1
1–10 years	179	87,973	2.0	1.1	1.0 (0.78, 1.3)
>10 years	195	108,092	1.8	0.95	0.81 (0.62, 1.1)
Predominant work[b]					
Light commercial	152	71,031	2.1	1.1	1.2 (0.93, 1.5)
Heavy commercial	197	104,676	1.9	1	1.0 (0.82, 1.3)
Drywall	73	40,476	1.8	0.95	0.94 (0.70, 1.3)
Millwrights	7	4,672	1.5	0.79	0.85 (0.43, 1.7)
Piledrivers	36	17,026	2.1	1.1	1.1 (0.80, 1.6)
Cabinet/fixture	4	2,046	2.0	1.1	1.1 (0.46, 2.6)
Residential	7	3,624	1.9	1	1.1 (0.57, 2.2)
Mixed	31	23,949	1.3	0.68	0.72 (0.50, 1.0)

*Person-time at risk stopped accumulating after individual became a case. Uses first claim in an eligible month.
[a]Rate per 1,000 months of insurance coverage.
[b]RR = rate compared to overall group (crude rate = 1.9). Adjusted for age, sex, time in the union and predominant task.

the models except for bronchitis, so the rate ratios for carpentry task for these disorders are unadjusted.

These internal comparisons demonstrated that rates of asthma increased with increasing age. Women had 1.7 times the rate of asthma as men, although the difference is not statistically significant as reflected in the wide confidence interval. Those in the union greater than ten years had a 40% decreased rate of asthma. The rate ratio compared to the overall group was highest for residential carpenters (1.7), but none of the predominant work categories are significantly different than the overall group mean.

Bronchitis also increased with age but not in a monotonic fashion. Women had a 35% lower rate of bronchitis than men, but again it is not statistically significant. By 10 years in the union, the rate was decreased but not to a statistically significant extent, and no differences were seen among the different types of predominant work.

Chronic bronchitis clearly increased with increasing age with a rate ratio of 5.6 (1.5, 20.2) for those over 60 years. Rates were not significantly different based on time in the union, sex, or predominant task. Those in the union between 1 and 10 years had 1.6 times the rate of those in the union less than a year. Cabinet and fixture workers had 2.7 times the rate of the overall group mean and women had a rate 3.7 times that of their male counterparts. These rate ratios were based on one and two cases, respectively, and are very unstable.

Chronic obstructive airway disease dramatically increased with increasing age. Rates increased with increasing time in the union. Women had three times the rate of men, and cabinet makers had high rate ratios but, again, these

TABLE V. Crude Rates, Crude Rate Ratios, and Adjusted Rate Ratios for Internal Comparisons of Rates of Lung Diseases Among Union Carpenters Washington State 1989–1992: Chronic Bronchitis (ICD-9 491)*

Covariate	# Cases	Months of coverage	Crude rate[a]	Crude RR	Adjusted RR[c] 95% CI
Age					
<30 years	5	54,706	0.10	1	1
30–44 years	18	148,231	0.12	1.3	1.3 (0.46, 3.5)
45–60 years	21	62,259	0.34	3.7	3.4 (1.2, 10.2)
60+ years	7	14,662	0.48	5.2	5.6 (1.5, 20.2)
Sex					
Males	49	275,408	0.18	1	1
Females	2	4,492	0.45	2.5	3.7 (0.87, 15.5)
Time in the union					
Up to 1 years	6	51,608	0.12	1	1
1–10 years	18	91,195	0.20	1.7	1.6 (0.61, 3.9)
>10 years	25	112,111	0.22	1.9	1.1 (0.40, 2.8)

			Rate (95% CI)[d]	Unadjusted RR[c]
Predominant work[b]				
Light commercial	15	73,613	0.20 (0.11, 0.33)	1.1
Heavy commercial	18	107,955	0.17 (0.10, 0.27)	0.94
Drywall	6	41,830	0.14 (0.05, 0.31)	0.78
Millwrights	0	4,745	— —	
Piledrivers	6	17,599	0.34 (0.13, 0.74)	1.9
Cabinet/fixture	1	2,081	0.48 (0.01, 2.6)	2.7
Residential	0	3,792	— —	—
Mixed	5	24,475	0.20 (0.06, 0.47)	1.1

*Person-time at risk stopped accumulating after individual became a case. Uses first claim in an eligible month.
[a]Rate per 1,000 months of insurance coverage.
[b]Predominant task not included in model; adjustment for age, sex, time in the union.
[c]RR = rate compared to overall group rate of .18 (0.13, 0.24).
[d]95% Poisson CI.

TABLE VI. Crude Rates, Crude Rate Ratios, and Adjusted Rate Ratios for Internal Comparisons of Rates of Lung Diseases Among Union Carpenters Washington State 1989–1992: Chronic Obstructive Airway Disease, NOC (ICD-9 496)*

Covariate	# Cases	Months of coverage	Crude rate[a]	Crude RR	Adjusted RR[c] 95% CI
Age					
<30 years	5	54,723	0.10	1	1
30–44 years	23	148,039	0.16	1.7	2.3 (0.66, 7.8)
45–60 years	46	61,797	0.74	8.2	10.3 (3.0, 35.5)
60+ years	16	14,435	1.1	12.1	14.9 (4.0, 56.1)
Sex					
Males	88	274,544	0.32	1	1
Females	2	4,492	0.45	1.4	3.1 (0.75, 13.0)
Time in the union					
Up to 1 years	8	51,549	0.16	1	1
1–10 years	19	91,094	0.21	1.3	1.1 (0.49, 2.6)
>10 years	59	111,461	0.53	3.4	1.4 (0.60, 2.9)

			Rate (95% CI)[d]	Unadjusted RR[c]
Predominant work[b]				
Light commercial	25	73,488	0.34 (0.22, 0.50)	1.1
Heavy commercial	30	107,649	0.27 (0.18, 0.39)	0.84
Drywall	9	41,708	0.21 (0.10, 0.40)	0.65
Millwrights	2	4,708	0.42 (0.05, 1.5)	1.3
Piledrivers	9	17,483	0.51 (0.23, 0.97)	1.6
Cabinet/fixture	2	2,100	0.95 (0.11, 3.4)	2.9
Residential	0	3,792	— —	
Mixed	11	24,345	0.45 (0.22, 0.80)	1.4

*Person-time at risk stopped accumulating after individual became a case. Uses first claim in an eligible month.
[a]Rate per 1,000 months of insurance coverage.
[b]Predominant task not included in model; adjustment for age, sex, time in the union.
[c]RR = rate compared to overall group rate of 0.32 (0.26, 0.40).
[d]Poisson 95% CI.

were both based on two cases among small groups of workers and must be regarded with some caution.

External Comparisons

Comparisons to NHIS Occupational Supplement 1988. The 12-month period prevalences of chronic bronchitis and asthma are presented for male carpenters between 1989 and 1992 and compared to the population estimates derived from the NHIS Occupational Supplement 1988 in Tables VII. The carpenters' period prevalence (%) of chronic bronchitis for the 4 years studied was less for comparable age groups of men than that reported in the NHIS Occupational Supplement. The period prevalence of asthma was less for male carpenters except between the ages of 45–65 than for other working men in the U.S. The carpenters' prevalence in this age category is more similar to the prevalence reported among other working age men of the same age (1.6%) with the carpenters' prevalence increasing gradually from 1.5 in 1989 to 2.1 in 1992.

Comparisons to SEER data for lung cancer. Standardized incidence ratios for cancer of the lung or bronchus using SEER rates for indirect adjustment are presented in Table VIII. The overall observed cases of lung cancer among the carpenters (SIR 1.3 when using all cases and time at risk or 1.2 when discounting the first 3 months to approximate incidence more closely) was not significantly different than

TABLE VII. Twelve Month Period Prevalence Rates Chronic Bronchitis (ICD 491) and Asthma (ICD 493) Comparisons to National Health Interview Survey, Occupational Health Supplement 1988*

Chronic Bronchitis				
	1989–1992			
Age	P-YR	# Cases	Average prevalence %	% Prev[a] NHIS
18–24 Males	1,565	2	0.13	0.86%
25–44 Males	15,050	21	0.14	1.0%
45–64 Males	6,185	28	0.45	1.7%
65–69 Males	194	1	0.52	3.9%
Asthma				
	1989–1992			
Age	P-YR	# Cases	Average prevalence %	% Prev[a] NHIS
18–24 Males	1,565	12	0.8	2.3
25–44 Males	15,050	176	1.2	2.1
45–64 Males	6,185	112	1.8	1.6
65–69 Males	194	0	—	3.3

*Age calculated for each person at mid-year of each year. Case = first claim for each carpenter for each diagnosis in that year. Prev % = # cases in each year divided by person-years of observation × 100.
[a]Answered 'yes' to question ''During the past 12 months have you had chronic bronchitis/asthma?'' (Among people who were currently working.)

TABLE VIII. Cancer of Lung and Bronchus (ICD-9 162.2–162.9): Male Carpenters of Western Washington 1989–1992*

Age category	Person-years[e] of observation	SEER[a] rate per 100,000 py's	OBS	EXP	SIR[b]
15–34 years old	8,836	0.6	1	0.05	20.0
35–44 years old	7,747	11.3	2	0.88	2.3
45–54 years old	3,784	68.6	8	2.6	3.1[c]
55–64 years old	2,405	236.8	2	5.7	0.35
65+ years old	219	499.3	0	1.1	—
Overall SIR (95% approximate confidence interval)			13	10.33	1.3 (0.67, 1.9)
Discounting the first 3 months of person-time observed					
Age category	Person-years[e] of observation	SEER[a] rate per 100,000 py's	OBS	EXP	SIR[b]
15–34 years old	7,582	0.6	1	0.05	20.0
35–44 years old	7,005	11.3	2	0.79	2.5
45–54 years old	3,439	68.6	6	2.3	2.6[d]
55–64 years old	2,232	236.8	2	5.2	0.38
65+ years old	212	499.3	0	1.1	—
Overall SIR (95% approximate confidence interval)			11	9.44	1.2 (0.59, 2.1)

*Overall SIR confidence limits represent 95% approximate estimates (Rothman KJ and Boise JD, 1979: Epidemiologic Analysis with a Programmable Calculator. NIH Publication No. 79-1649, Washington, D.C.: U.S. Dept of Health) from Checkoway, Research Methods in Occupational Epidemiology. Notes: No cases of cancer of the lung or bronchus identified among women in the cohort overall person-years of observation for women = 330 discounting first 3 months person-years of observation = 282.
[a]SEER (Surveillance, Epidemiology, and End Results) Program rates are for 1990–1991.
[b]SIR = Standardized incidence ratio.
[c]Significantly different from 1 at .005 level (Chi Sq statistic).
[d]Significantly different from 1 at .025 level (Chi Sq statistic).
[e]Person-time at risk stopped accumulating when the person became a case.

expected based on national SEER rates 1990–1991. However, the SIR is significantly increased for carpenters between the ages of 45 and 54.

Case-Control Study

Pool of cases compared to controls. There were no significant differences between the pool of cases and controls by age, sex, time in the union, percent unable to locate or response rates (Table IX). Poisson regression analyses performed using the pool of cases and controls revealed results comparable to those obtained when analyzing the entire cohort (Table III), indicating that the controls were comparable to the non-cases in the entire cohort in respect to age, sex, and time in the union.

Response rates. Of the 651 different individuals in the entire pool of cases and controls, 366 (56.2%) individuals returned the questionnaire. Fifty-two individuals were unable to be located or were deceased at the time of follow up (8.6% of controls and 6.4% of cases). Among individuals that we were able to contact, the response rate was 61%. Forty-three percent of the matched triads (95/220) did not have a matched pair that responded. To maximize the use of the available data, the decision was made to perform an unmatched analysis.

As seen in Table IX, respondents were older than nonrespondents (mean 41.7 years vs. 37.9 years, $P = 0.03$), and they had been in the union longer (mean 12.3 years vs. 6.9 years, $P < 0.001$). They were not different in regard to sex or the percentage of cases. Among those responding, cases and controls were not significantly different from each other in regard to age, time in the union, sex, race, educational level, or months of insurance eligibility.

Responses to medical history questions. Responses to questions regarding respiratory problems are summarized by case-control status and for all subjects in Table X. A prior

TABLE IX. Cases Compared to Controls and Respondents Compared to Nonrespondents

Total pool (n = 660)	Case n = 220	Control[b] n = 431	*P* value[a]
Mean age in years	40.0	40.0	0.81
Mean time in union in years	9.5	10.1	0.55
Sex (% men)	96.8	97.3	0.72
Unable to locate (%)	6.4	8.6	0.31
% responded	53.5	58.0	0.29
% responded if able to contact	57.3	63.6	0.13
	Respondent n = 368	**Non-respondent n = 283**	***P* value[a]**
Mean age in years	41.7	37.9	$P = .03$
Mean time in union in years	12.3	6.9	$P < .001$
Sex (% men)	96.2	97.9	$P = 0.22$
% cases	32.1	36.0	$P = 0.29$

[a]*P* values based on t-tests for continuous variables and chi square for categorical variables.
[b]Individuals were allowed to be a control for more than one case.

diagnosis of asthma was reported by 62.4% of cases and 10.6% of controls. Thirty-seven individuals reported a diagnosis of asthma before the age of 20. This included 25 cases (21.2%) and 12 controls (4.6%). Nine (24%) of these individuals who reported asthma before the age of 20 reported their diagnosis under the age of two.

Substances reported to cause breathing problems. There were 161 individuals (87 cases, 74 controls) who reported breathing problems at work. Of these individuals, 133 (70 cases, 63 controls) described substances they believed caused their problems. The most common substances included undescribed dusts (14.4%), concrete or cement dusts (9%), fiberglass, rock wool, or mineral wool (9%), wood dusts (8%), drywall dusts (5.4%), paints or varnishes (5.4%), gasoline or diesel fumes (6.7%), and cigarette smoke or smoking (6.2%).

Crude odds ratios for demographic variables, tobacco exposures, and household conditions. In Table XI, crude odds ratios and 95% confidence intervals (logit) are presented for demographic variables, tobacco use, and various household conditions. Significantly reduced odds ratios for asthma were seen for smokers in the home and use of a fireplace or wood stove in the home.

Distribution of exposures and odds ratios for occupational and miscellaneous exposures. The distribution of occupational exposures by case-control status, crude odds ratios, and odds ratios adjusted for age, sex, time in the union, and ever smoking history are presented in Table XII. Odds ratios for exposures to cotton dust, hay, enamel paints (oil based), epoxy paints, lacquers, latex paints (water based), polyurethane products, varnishes/stains, animal fur/wastes, enzymes, and mold were all significantly elevated.

Comparison of findings using Burney's discriminant function predictor (DFP). Based on the case definition of a medical claim with the ICD-9 code of asthma (493) there were 118 cases and 250 controls among the respondents. Based on Burney's discriminant function predictor (DFP), there were 140 cases and 228 controls. The cases and controls defined in these two different ways are compared in Table XIII. Assuming Burney's definition as a gold standard, which has been validated for its ability to predict bronchial response to histamine [Burney et al., 1989], the sensitivity of the ICD-9 diagnosis used to initially identify cases and controls was 0.56 and the specificity was 0.83. (Positive predictive value ICD-9 493 = 0.67, negative predictive value ICD-9 493 = 0.76).

Using Burney's case definition the majority of household exposures were not of significance, similar to findings using the ICD-9 case definition. However, the presence of an asthmatic in the home (OR 2.1; 95% CI 1.0, 4.4) was significant, as was the history of ever smoking (OR 1.7; 95% CI 1.0, 2.6), and exposure to smokers at work (OR 2.0; 95% CI 1.3, 3.1). The odds ratios for passive smoking exposure appear to increase with increasing hr of exposure (compared to no exposure 1–4 hr OR 1.7, 4–8 hours OR = 2.7, >8 hr OR = 2.3), and was significantly increased for the 4–8 hr/day exposure category.

In Table XIV crude and adjusted odds ratios are presented for all exposures which were significantly elevated using either the ICD-9 case definition or Burney's DFP. Odds ratios for more exposures were significantly elevated using the Burney case definition. Using this definition, elevated odds ratios were seen for exposures to multiple dusts including cement, drywall, grain or flour, hay, lime, sweeping/demolition, silica, talc, vermiculite/perlite filler materials, and wood bark. Elevated odds ratios were also seen for epoxy paints, glues, caulks; multiple metal dusts or fumes (aluminum, cobalt, nickel, platinum, and stainless steel); acids, alkali, animal fur/wastes, concrete form oils, enzymes, exhaust from engines, mold, fumes from heated plastics, printing inks and oils, styrene, and urethane foam insulation. In contrast, the odds ratios for paints, varnishes and stains were reduced somewhat compared to those from the ICD-9 definition, with epoxy paints being the only one which remained elevated at a level of statistical significance.

TABLE X. Affirmative Responses to Medical History Questions (Cases defined by ICD-9 code 493)

	Case (n = 118)	Control (n = 250)	Total (n = 368)
Ever diagnosed with:			
Bronchitis	60 (50.8%)	78 (31.5%)	138 (37.5)
Chronic bronchitis	22 (18.8%)	18 (7.3%)	40 (10.9%)
Emphysema	8 (6.8%)	3 (1.2%)	11 (3.0%)
Asthma	73 (62.4%)	26 (10.6%)	99 (26.9%)
Asbestosis	5 (4.2%)	2 (0.8%)	7 (1.9%)
Silicosis	0	0	0
Lung cancer	1 (0.8%)	1 (0.4%)	2 (0.5%)
In last 12 months:			
Wheezing/whistling[a]	96 (81.4%)	100 (40.2%)	196 (53.4%)
Tightness on waking	79 (66.9%)	84 (33.7%)	163 (44.4%)
SOB in day w/o exertion	70 (59.8%)	44 (17.7%)	114 (31.1%)
SOB after exercise	72 (61.0%)	56 (22.5%)	128 (34.9%)
Awakened at nite SOB[a]	46 (39.3%)	20 (8.1%)	66 (18.1%)
Awakened at nite by cough	66 (57.4%)	94 (37.9%)	160 (44.1%)
General			
Usually cough in AM	56 (48.7%)	76 (30.8%)	132 (36.5%)
Best describes breathing:			
Never trouble	35 (29.7%)	182 (72.8%)	217 (59.0%)
Regular trouble[a]	31 (26.3%)	30 (12.0%)	61 (16.6%)
Never right[a]	51 (43.2%)	30 (12.0%)	81 (22.0%)
Chest tight with dust/animals[a]	44 (40.4%)	27 (11.2%)	71 (20.2%)
SOB with dust/animals	50 (45.0%)	23 (9.7%)	73 (21.0%)
Ever had asthma attack?	67 (59.3%)	27 (11.2%)	94 (26.6%)
Asthma attack last 12 months?	57 (59.4%)	9 (8.0%)	66 (31.7%)

[a]Questions used in Burney Definition.

Behavior of Covariates in Adjusted Models Based on Different Case Definitions

In the adjusted models, using an ICD-9 case definition, the odds ratios for the covariates age, sex, time in the union, and ever smoking did not reach statistical significance. When using the DFP case definition, age never achieved statistical significance but the other covariates did achieve statistical significance in some models. The odds ratio for women compared to men ranged from 3.2 to 4.5, and the odds ratio for ever smoking ranged from 1.6 to 1.9. Time in the union appeared to be protective with values ranging from 0.5 to 0.7 for 1–10 years and 10 plus years compared to those with less than one year of time in the union.

DISCUSSION

Cohort Analyses

Bronchitis, asthma, chronic bronchitis, and chronic obstructive airway disease were the most common lung disorders for which this group of carpenters sought medical care. No statistically significant differences were seen for men and women for the four lung diseases we evaluated with these internal comparisons—not surprising since the women represent only 2% of the cohort. Women had higher rates of the more chronic disorders of asthma, chronic bronchitis, and chronic obstructive airway disease but lower rates for bronchitis. The more chronic of these respiratory diseases—asthma, chronic bronchitis, and chronic obstructive airway disease—appear to increase with age among this working population. Chronic bronchitis and chronic obstructive airway disease increase in a dramatic monotonic fashion with age. These findings are consistent with other population-based studies in which older age has been reported to be associated with increased bronchial hyperresponsiveness [Rijcken et al., 1993], increased prevalence of bronchial asthma and chronic obstructive lung disease [Bakke et al., 1992], and increased hospitalization for chronic obstructive pulmonary disease [Vilkman et al., 1996].

Individuals whose locals do predominantly light commercial work had higher rates of bronchitis. The rate

TABLE XI. Demographic Variables, Smoking, and Home Exposures Crude Odds Ratios and 95% Confidence Intervals (logit) (Cases defined by ICD-9 code 493)

	N	OR (95% CI)
Demographic information		
Age	368	
<30	43	1
30–39	135	0.97 (0.46, 2.1)
40–49	95	1.4 (0.65, 3.0)
50–59	65	0.82 (0.35, 1.9)
>60	30	1.5 (0.58, 4.1)
Race	361	
White	346	1
Other	15	1.4 (0.49, 4.0)
Sex	368	
Male	354	1
Female	14	0.84 (0.25, 2.7)
Time in the Union	342	
<1 year	32	1
1–9 years	138	0.73 (0.33, 1.6)
>=10 years	172	0.65 (0.30, 1.4)
Months of insurance eligibility		
<=1 year	193	1
1–2 years	96	0.79 (0.46, 1.3)
2–3 years	46	0.88 (0.44, 1.8)
3–4 years	33	1.3 (0.61, 2.8)
Tobacco use		
Smoked in the last month	242	
No	143	1
Yes	99	0.77 (0.44, 1.3)
Ever smoked	355	
No	116	1
Yes	239	1.1 (0.67, 1.7)
Smokers at home	338	
No	239	1
Yes	99	0.55 (0.32, 0.93)[a]
Smokers at work	332	
No	170	1
Yes	162	1.2 (0.76, 1.9)
Passive smoke exposure	304	
None	61	1
1–4 hours/day	118	1.3 (0.64, 2.6)
4–8 hours/day	89	1.8 (0.89, 3.7)
>8 hours/day	36	0.93 (0.36, 2.4)
Household conditions		
Lives in mobile home	362	
No	323	1
Yes	39	0.50 (0.22, 1.1)
Water damage to home	361	
No	292	1
Yes	69	0.57 (0.31, 1.1)
Basement in home	360	
No	257	1
Yes	103	1.2 (0.72, 1.9)
Water in basement	182 (only answer if have basement)	
No	163	1
Yes	19	0.51 (0.16, 1.6)
Mold in home	353	
No	241	1
Yes	112	0.85 (0.52, 1.4)
Humidifier in home	355	
No	321	1
Yes	34	0.98 (0.46, 2.1)
Fireplace/wood stove for heat	368	
No	190	1
Yes	170	0.63 (0.41, 0.99)[a]
Gas fireplace heat	368	
No	343	1
Yes	25	1.0 (0.42, 2.4)
Electric heat	368	
No	193	1
Yes	175	0.95 (0.61, 1.5)
Gas furnace	368	
No	260	1
Yes	108	1.1 (0.67, 1.8)
Oil furnace	368	
No	326	1
Yes	42	0.83 (0.41, 1.7)
Heat pump	368	
No	347	1
Yes	21	1.3 (0.53, 3.3)
Cook with gas	368	
No	314	1
Yes	54	0.71 (0.37, 1.4)
Cook with electricity	368	
No	63	1
Yes	305	1.5 (0.80, 2.7)
Asthmatic in home	359	
No	325	1
Yes	34	1.5 (0.72, 3.1)

[a]Significant at 0.05 level.

ratio of 1.6 is diminished compared to what it would be if comparisons had been made to a low risk reference group as opposed to the overall group mean, a point which should be borne in mind in assigning importance to the results. Higher rates of chronic bronchitis and chronic obstructive lung disease were seen among cabinet makers and higher rates of asthma were seen for residential carpenters, but these differences were based on very small numbers and are not statistically significant.

External comparisons give some indication of excess respiratory problems among this working cohort of union carpenters. This is documented by an increased incidence of lung cancer among males aged 45–54, and a possible excess in the period prevalence of asthma among men aged 45–64. Although the prevalence of asthma was very close to that reported in the NHIS Occupational Supplement, the actual prevalence of asthma among 45–64-year-old male carpenters may be higher than among other working males of the same age since the NHIS used self-report, and we required an encounter with a physician with an ICD-9 diagnosis of asthma resulting on the medical claim.

The excess incidence of lung cancer among 45–54-year-olds in this working cohort is consistent with mortality findings of others. Milham's early study of mortality among members of the UBC [NIOSH, 1974] first reported an elevated standardized mortality ratio (SMR) for lung cancer and mesothelioma for construction carpenters, and the excess was largely attributed to exposure to asbestos. Since then, a number of investigators have reported excess deaths due to lung cancer among carpenters [Firth et al., 1993; Zahm et al., 1989; Stellman and Garfinkel, 1984]. A recent proportionate mortality ratio (PMR) study by Robinson (1997) of UBC members who died between 1987 and 1990 again documented excess lung cancer deaths among carpenters last employed in construction, but not among carpenters last employed in wood products. Excess deaths from lung cancer were seen in both PMR and proportionate cancer mortality ratio (PCMR) analyses used to dampen the healthy worker effect. Our cohort is almost entirely construction carpenters with very few employed in the wood products industry (cabinet makers n = 72 [0.7%]). The fact that we saw no excess of lung cancer incidence after age 54 could be related to very little observation of those over the age of 65 and the fact that we had restricted our cohort to active carpenters who had to have worked at least 3 months during our 4-year observation period. All of these things raise concern about the respiratory health of working carpenters 45-years-old and greater.

Case-Control Analyses

The case-control study explored a number of factors which might contribute to asthma among a group of predominantly construction carpenters. Initially, cases were defined based on an ICD-9 diagnosis of asthma from private health insurance or workers' compensation claims between 1989 and 1992. Later analyses were based on a reclassification of cases and controls based on response to items included in Burney's discriminant function predictor of a bronchial response to histamine.

Using either case definition, odds ratios were significantly elevated for exposure to hay, epoxy paints, animals, enzymes, and molds. Exposure to mold in the home was not of significance, whereas exposure to mold in workplace exposures was of significance. These exposures, which were consistently associated with asthma among this study population using either case definition, have been reported to be associated with asthma by others [Chan-Yeung, 1990; Reilly et al., 1994; Kanerva et al., 1994]. The fact that we found exposures to molds in the workplace of significance but not in the home could relate to the amount of exposure. Exposures in the workplace, such as in the demolition of buildings, could expose the individual to a greater amount of mold spores [Rautiala et al., 1996].

Although the width of the confidence intervals varied across the two case definitions used, the odds ratios for paints, varnishes, and stains were consistently elevated, with epoxy paint consistently of statistical significance. Varnishes used in woodworking contain urea resins with formaldehyde as a curing agent, and the incorrect use of polyurethane can lead to respiratory exposure to isocyanates [IARC, 1981]. Both formaldehyde and isocyanates are reported as causes of occupational asthma [Reilly et al., 1994]. Latex, or water-based paints, have lower concentrations of volatile organic compounds (VOC) than solvent based paints. The chemical composition of the VOCs emitted from latex paint is different from those emitted from solvent based paints, with more polar compounds such as plastic monomers, glycols, and glycol ethers in latex paints. Other additives in water-based paints include biocides, surfactants, pigments, binders, and amines which could present respiratory health hazards [Wieslander et al., 1994].

Using Burney's DFP definition, odds ratios were elevated for women and ever smoking history. A likely dose-response was seen for hours per day of passive smoke exposure. The elevated odds ratio for women compared to men using Burney's DFP is consistent with our internal comparisons using Poisson regression in which the rate ratio for women was 1.7 (0.68, 4.1), and with elevated rates of outpatient visits for asthma for women seen in the National Ambulatory Medical Care Survey [U.S. Dept. of Health and Human Services, 1995]. Also consistent with these findings, lower rates of asthma were seen among individuals who had been in the union between 1 and 10 years compared to those in the union less than 1 year using Poisson regression. The decreased risk of asthma among those in the union less than 1 year could reflect self-selection out of carpentry by those experiencing respiratory problems.

TABLE XII. Occupational Exposures by Case-Control Status, Crude and Adjusted Odds Ratios (Cases defined by ICD-9 code 493) Unionized Carpenters Washington State 1989–92

	Numbers exposed			
	Cases (n = 118) n(%)[a]	Controls (n = 250) n(%)[a]	Crude OR (95% CI)	Adjusted[b] OR (95% CI)
Dusts				
Asbestos	45 (39.5)	84 (35.2)	1.2 (0.76, 1.9)	1.2 (0.69, 1.6)
Cement	102 (88.7)	215 (87.4)	1.3 (0.57, 2.3)	1.2 (0.58, 2.4)
Coal	2 (1.8)	11 (4.6)	0.38 (0.08, 1.7)	0.35 (0.07, 1.6)
Cotton	6 (5.5)	7 (2.9)	1.9 (0.63, 5.9)	3.3 (2.0, 4.6)[c]
Drywall (plaster)	104 (91.2)	214 (87.0)	1.6 (0.74, 3.3)	1.7 (0.79, 3.6)
Fiberglass/Mineral wool/rock wool	95 (81.9)	181 (73.9)	1.6 (0.92, 2.8)	1.6 (0.93, 2.9)
Grain or flour	12 (10.5)	19 (7.9)	1.4 (0.64, 2.9)	1.8 (0.80, 2.7)
Hay	21 (18.9)	27 (11.3)	1.8 (0.98, 3.4)	2.1 (1.1, 4.1)[c]
Lime	27 (24.3)	47 (19.6)	1.3 (0.77, 2.3)	1.4 (0.80, 2.5)
Mixed dust—sweeping/demolition	108 (93.9)	232 (94.3)	0.93 (0.37, 2.4)	1.1 (0.15, 2.1)
Particle board	88 (75.2)	177 (72.0)	1.2 (0.72, 2.0)	1.1 (0.69, 1.7)
Plastic	24 (21.4)	65 (27.0)	0.74 (0.43, 1.3)	1.0 (0.99, 1.1)
Silica	53 (46.9)	128 (52.9)	0.79 (0.50, 1.2)	0.81 (0.51, 1.3)
Talc	6 (5.5)	12 (5.1)	1.1 (0.41, 3.0)	1.3 (0.24, 2.4)
Vermiculite/Perlite filler materials	20 (18.0)	45 (19.0)	0.94 (0.52, 1.7)	0.97 (0.53, 1.8)
Wood bark	41 (37.3)	79 (33.8)	1.2 (0.72, 1.9)	1.1 (0.70, 1.8)
Wood	109 (94.8)	225 (91.8)	1.6 (0.63, 4.1)	1.5 (0.65, 2.6)
Paints, Varnishes and Stains				
Enamels (oil-based)	81 (71.7)	134 (55.1)	2.1 (1.3, 3.3)[c]	2.2 (1.3, 3.6)[c]
Epoxy paints	71 (62.8)	117 (48.0)	1.8 (1.2, 2.9)[c]	2.0 (1.3, 3.2)[c]
Lacquers	73 (64.6)	132 (54.1)	1.5 (0.98, 2.5)	1.6 (1.0, 2.6)[c]
Latex paints (water based)	89 (77.4)	154 (63.4)	2.0 (1.2, 3.3)[c]	2.1 (1.2, 3.5)[c]
Polyurethane products	77 (68.1)	138 (56.8)	1.5 (0.97, 2.5)	1.6 (1.0, 2.6)[c]
Varnishes/stains	77 (68.1)	141 (57.6)	1.6 (0.99, 2.5)	1.7 (1.0, 2.7)[c]
Wood sealers	61 (52.6)	110 (44.9)	1.4 (0.87, 2.1)	1.5 (0.93, 2.3)
Glues/Resins/Caulks				
Glues	85 (76.6)	167 (70.8)	1.4 (0.80, 2.3)	1.4 (0.84, 2.5)
Resins (epoxy, foam, acrylic, polyester)	66 (58.4)	119 (50.0)	1.4 (0.89, 2.2)	1.4 (0.86, 2.2)
Caulks (epoxy, silicone, latex)	99 (86.8)	198 (83.2)	1.3 (0.70, 2.5)	1.3 (0.68, 2.6)
Metal Dusts or Fumes				
Aluminum dusts or fumes	32 (27.8)	63 (25.7)	1.1 (0.68, 1.8)	1.1 (0.67, 1.9)
Cobalt dusts or fumes	7 (6.3)	12 (5.0)	1.3 (0.48, 3.3)	1.3 (0.31, 2.3)
Nickel dusts or fumes	6 (5.3)	7 (2.9)	1.9 (0.61, 5.7)	2.1 (0.66, 6.9)
Platinum dusts or fumes	3 (2.6)	5 (2.1)	1.3 (0.30, 5.5)	1.6 (0.06, 3.1)
Stainless steel (Chromium dusts or fumes)	21 (18.4)	31 (12.8)	1.5 (0.84, 2.8)	1.8 (0.95, 3.4)
Tungsten Carbide dusts or fumes	14 (12.3)	27 (11.3)	1.1 (0.55, 2.2)	1.2 (0.57, 2.4)
Vanadium dusts or fumes	4 (3.6)	8 (3.4)	1.1 (0.32, 3.7)	1.2 (0.34, 2.5)
Processes Using Metals				
Metal plating	10 (9.2)	17 (7.2)	1.3 (0.57, 2.9)	1.3 (0.46, 2.2)
Soldering or brazing fumes	53 (46.1)	92 (38.0)	1.4 (0.89, 2.2)	1.4 (0.93, 1.8)
Welding or cutting fumes	88 (75.9)	184 (74.8)	1.1 (0.63, 1.8)	1.1 (0.64, 1.9)

(continued)

TABLE XII. Occupational Exposures by Case-Control Status, Crude and Adjusted Odds Ratios (Cases defined by ICD-9 code 493) (continued)

	Numbers exposed			
	Cases (n = 118) n(%)[a]	Controls (n = 250) n(%)[a]	Crude OR (95% CI)	Adjusted[b] OR (95% CI)
Miscellaneous Exposures				
Acids (muriatic, sulfuric)	31 (27.7)	50 (21.1)	1.4 (0.85, 2.4)	1.4 (0.83, 2.4)
Alkali (caustics, lye, sodium hydroxide)	17 (15.2)	27 (11.3)	1.4 (0.73, 2.7)	1.3 (0.66, 2.1)
Ammonia	31 (27.2)	47 (19.8)	1.5 (0.90, 2.6)	1.6 (0.93, 2.8)
Animals (fur/wastes)	74 (64.4)	121 (50.2)	1.8 (1.1, 2.8)[c]	1.9 (1.2, 3.1)[c]
Chlorine (pool maintenance, paper mill)	36 (31.6)	69 (28.9)	1.1 (0.70, 1.8)	1.2 (0.74, 1.7)
Cigarette smoke	102 (87.2)	216 (88.2)	0.91 (0.47, 1.8)	0.95 (0.27, 1.6)
Concrete form oils	92 (78.6)	177 (72.8)	1.4 (0.81, 2.3)	1.4 (0.81, 2.4)
Cutting oils (coolant/oil mists)	57 (49.6)	95 (39.8)	1.5 (0.95, 2.3)	1.5 (0.92, 2.3)
Drug pharmaceutical manufacturing	1 (0.87)	5 (2.1)	0.41 (0.04, 3.6)	0.55 (0.05, 5.5)
Dyes	4 (3.5)	6 (2.8)	1.4 (0.39, 5.1)	1.8 (0.36, 3.2)
Enzymes (detergent, plastic, or pharmaceutical industry)	21 (18.4)	27 (11.3)	1.8 (0.96, 3.3)	2.0 (1.1, 3.9)[c]
Exhaust from engines	93 (79.5)	198 (80.8)	0.92 (0.54, 1.6)	1.0 (0.57, 1.8)
Formaldehyde or glutaraldehyde vapor	12 (10.8)	34 (14.1)	0.74 (0.37, 1.5)	0.77 (0.04, 1.5)
Fumes from heated plastics	23 (20.4)	41 (17.0)	1.2 (0.71, 2.2)	1.4 (0.77, 2.5)
Gasoline (service station attendant, mechanic)	57 (49.1)	106 (44.2)	1.2 (0.78, 1.9)	1.3 (0.80, 2.0)
Glycols (antifreeze, paints)	35 (31.0)	75 (31.4)	0.98 (0.61, 1.6)	1.0 (0.54, 1.5)
Mold	44 (38.9)	61 (28.9)	1.8 (1.1, 2.9)[c]	2.0 (1.2, 3.3)[c]
Pesticides, insecticides, herbicides	33 (29.0)	66 (27.4)	1.1 (0.66, 1.8)	1.1 (0.61, 1.6)
Printing inks and oils	10 (8.9)	13 (5.5)	1.7 (0.71, 4.0)	2.3 (0.90, 5.9)
Seafood processing	4 (3.5)	17 (7.1)	0.47 (0.16, 1.4)	0.60 (0.19, 1.9)
Smoke from combustion	32 (27.6)	76 (31.7)	0.82 (0.50, 1.3)	0.84 (0.33, 1.3)
Styrene	20 (17.4)	26 (10.9)	1.7 (0.91, 3.2)	1.7 (0.89, 3.3)
Tar (coal or petroleum)	38 (33.6)	86 (35.7)	0.91 (0.57, 1.5)	0.94 (0.46, 1.4)
Urethane foam insulation	56 (49.1)	95 (39.8)	1.5 (0.93, 2.3)	1.4 (0.88, 2.2)

[a]Percent exposed of those who responded to question.
[b]Adjusted for age, sex, time in the union, and ever smoking history.
[c]Significant at 0.05 level.

Strengths and Limitations

These analyses relied on existing data sources, specifically claims data, to provide the events of interest. The use of claims data does involve some lag in getting appropriate claims, and for a case to be recognized in these existing data sources, a claim must have been filed. Anything which influences whether a person files a claim, or under what system they choose to file the claim, will influence the recognition of the case.

Employers who self-insure for workers' compensation in the State of Washington are not required to report to the Department of Labor and Industries claims which require medical care but do not result in lost time from work, and self-insured employers do not have to report until after the claim is closed. L&I does not keep records of medical care rendered for these self-insured claims. Because of these reporting practices, it is possible that we missed a few cases of lung disease and the care associated with these cases. However, based on the small percentage of lung disease claims contributed by workers' compensation ($<$6%), the overall magnitude of error is likely very small.

Limited personal information is available in administrative data such as these. Diagnoses assigned to claims may be presumptive and later ruled out, and coding errors occur. The magnitude of these problems cannot be discerned without detailed information from the workers involved and access to actual medical records. However, any errors of this nature

TABLE XIII. Comparison of ICD-9 Case Definition with Burney's Discriminant Function Predictor*

ICD-9 definnition	Burney's DFP		
	Case	Control	TOTAL
Case	79[a]	39[b]	118[(a+b)]
Control	61[c]	189[d]	250[(c+d)]
TOTAL	140[(a+c)]	228[(b+d)]	368

*Sensitivity = a/a + c = 79/140 = 0.56. Specificity = d/b + d = 189/228 = 0.83. PV + = a/a + b = 79/118 = 0.67. PV − = d/c + d = 189/250 = 0.76.

should bias results toward the null in the case-control analyses, as both cases and controls should experience similar misclassification.

Time in the union, which was controlled for in the Poisson regression analyses and in the case-control analyses, is not a marker of time as a carpenter since many carpenters join the union after years of experience. Our classification of predominant task of the union locals could also create misclassification bias. This is a crude aggregate measure and the groupings are not discrete. Even though a local may perform predominantly one task, this does not mean that it is the only type of work done by members of that local, and there is likely to be significant overlap in the nature of the tasks that people from the different locals perform. This could explain our inability to more clearly discern differences by predominant type of carpentry work, if such differences do exist. For the cohort analyses we did not have information on smoking, an obviously important risk factor for lung disease among a group of workers with known high prevalence of smoking. Carpenters, defined by census code 567, had an estimated smoking prevalence of 45.5% between 1987 and 1990 based on National Health Interview Survey data [Nelson et al., 1994]. Among those completing the case-control questionnaire, 65% reported smoking at sometime and 27% reported smoking in the last month.

Despite these limitations, claims data analyses have advantages. They do not require the personal cooperation of subjects, and the recall of events is not a problem. Claims allow access to a lot of information about morbidity of disorders of possible occupational origin—an area in which information is lacking among most occupational cohorts and is entirely missing from workers' compensation data alone. The use of combined data sources allowed the identification of both numerator (events of interest) and denominator (time at risk) data. In an attempt to gather both numerator and denominator data in comparable ways, we analyzed claims that occurred in months in which the individual had health insurance coverage, using person-months (or -years) as the time at risk. Since very few claims were identified through workers' compensation records, this use of months of insurance eligibility seems a more appropriate denominator than hours of work. The ability to generate rates through the use of these combined data sources provides information that can be used for monitoring trends, but changes in health insurance benefits or requirements must be considered in comparing rates based on medical claims over time.

Due to the level of detail requested in the case-control questionnaire, the response rate of 61% seems reasonably good. Respondents were older and had more union experience than nonrespondents. Among the carpenters who were contacted by phone, there was some concern expressed about the confidentiality of the data and fear of employers obtaining access to their responses. A number of these late responders were no longer in the union and had not felt their responses were desired. These things raise some concern about possible bias.

A problem in the study of asthma is the lack of clear, standardized criteria by which to define this disease. From our study base, we were able to identify cases of asthma defined by an ICD-9 code only. These cases represented a mix of incident and prevalent cases. For a person to have received an ICD-9 code diagnosis, he or she must have visited a physician. Although this definition was fairly specific it was not very sensitive.

Burney's DFP is based on a series of questions from the International Union Against Tuberculosis and Lung Disease (IUATLD) questionnaire chosen for their ability to predict bronchial response to histamine in adults aged 18–64. The items do not differentiate reactivity associated with a positive skin test and that associated with smoking [Burney et al., 1989]. The questionnaire items for the DFP have the distinct advantage that they have been tested against a standard, objective measurement, but bronchial reactivity is not itself specific to asthma. A negative test does not rule out asthma. While we feel that Burney's DFP improved our ability to appropriately classify cases, it is still a less than perfect measure.

By reclassifying our cases and controls based on Burney's DFP, we realize that we did not capture all cases defined in this manner from the study base. In fact, we could not have done so without surveying the entire population of carpenters in our cohort, which was not feasible. Nondifferential misclassification of cases would be predicted to bias results toward the null [Kleinbaum et al., 1982]. This is a possible explanation for the differences in the results we obtained using these two different definitions of cases with more exposures of significance using Burney's DFP case definition. This is also a likely explanation for the differences in the behavior of the covariates for the different definitions of asthma.

Our original case definition included individuals who had an ICD-9 diagnosis of asthma between 1989 and 1992. Our questionnaire was mailed to subjects in 1995. Some of the individuals in our study may have received an ICD-9

TABLE XIV. Crude and Adjusted Odds Ratios for Occupational Exposures of Statistical Significance using Either Case Definition Unionized Carpenters Washington State 1989–1992

	Case defined by ICD9 493		Case defined by Burney DFP	
	Crude OR (95% CI)	Adjusted[a] OR (95% CI)	Crude OR (95% CI)	Adjusted[a] OR (95% CI)
Dusts				
Cement	1.3 (0.57, 2.3)	1.2 (0.58, 2.4)	2.3 (1.1, 4.8)[b]	2.3 (1.1, 4.9)[b]
Cotton	1.9 (0.63, 5.9)	3.3 (2.0, 4.6)[b]	1.5 (0.47, 4.5)	1.6 (0.38, 2.9)
Drywall (plaster)	1.6 (0.74, 3.3)	1.7 (0.79, 3.6)	2.9 (1.3, 6.5)[b]	3.3 (1.5, 7.5)[b]
Grain or flour	1.4 (0.64, 2.9)	1.8 (0.80, 2.7)	2.2 (1.0, 4.6)[b]	3.0 (1.4, 7.0)[b]
Hay	1.8 (0.98, 3.4)	2.1 (1.1, 4.1)[b]	2.3 (1.2, 4.2)[b]	3.5 (1.8, 6.9)[b]
Lime	1.3 (0.77, 2.3)	1.4 (0.80, 2.5)	2.8 (1.6, 4.7)[b]	3.3 (1.9, 5.7)[b]
Mixed dust—sweeping/demolition	0.93 (0.37, 2.4)	1.1 (0.15, 2.1)	2.1 (0.74, 5.8)	2.6 (1.6, 3.8)[b]
Silica	0.79 (0.50, 1.2)	0.81 (0.51, 1.3)	1.6 (1.1, 2.5)[b]	1.6 (1.0, 2.5)[b]
Talc	1.1 (0.41, 3.0)	1.3 (0.24, 2.4)	1.8 (0.69, 4.6)	2.3 (1.3, 3.4)[b]
Vermiculite/Perlite filler materials	0.94 (0.52, 1.7)	0.97 (0.53, 1.8)	1.8 (1.0, 3.1)[b]	2.2 (1.2, 5.3)[b]
Wood bark	1.2 (0.72, 1.9)	1.1 (0.70, 1.8)	1.5 (0.98, 2.4)[b]	1.7 (1.0, 2.7)[b]
Paints, Varnishes, and Stains				
Enamels (oil-based)	2.1 (1.3, 3.3)[b]	2.2 (1.3, 3.6)[b]	1.3 (0.81, 2.0)	1.3 (0.82, 2.1)
Epoxy paints	1.8 (1.2, 2.9)[b]	2.0 (1.3, 3.2)[b]	1.8 (1.2, 2.8)[b]	1.9 (1.2, 3.0)[b]
Lacquers	1.5 (0.98, 2.5)	1.6 (1.0, 2.6)[b]	1.3 (0.84, 2.0)	1.3 (0.85, 2.1)
Latex paints (water based)	2.0 (1.2, 3.3)[b]	2.1 (1.2, 3.5)[b]	1.3 (0.80, 2.0)	1.4 (0.84, 2.2)
Polyurethane products	1.5 (0.97, 2.5)	1.6 (1.0, 2.6)[b]	1.5 (0.95, 2.3)	1.6 (0.98, 2.5)
Varnishes/stains	1.6 (0.99, 2.5)	1.7 (1.0, 2.7)[b]	1.2 (0.79, 1.90)	1.3 (0.81, 2.0)
Glues/Resins/Caulks				
Glues	1.4 (0.80, 2.3)	1.4 (0.84, 2.5)	1.5 (0.94, 2.6)	1.7 (1.0, 2.9)[b]
Caulks (epoxy, silicone, latex)	1.3 (0.70, 2.5)	1.3 (0.68, 2.6)	1.8 (0.94, 3.4)	2.1 (1.1, 4.2)[b]
Metal Dusts or Fumes				
Aluminum dusts or fumes	1.1 (0.68, 1.8)	1.1 (0.67, 1.9)	1.7 (1.0, 2.7)[b]	1.9 (1.1, 3.1)[b]
Cobalt dusts or fumes	1.3 (0.48, 3.3)	1.3 (0.31, 2.3)	2.0 (0.79, 5.0)	2.3 (1.4, 3.3)[b]
Nickel dusts or fumes	1.9 (0.61, 5.7)	2.1 (0.66, 6.9)	2.8 (0.91, 8.8)	4.2 (1.2, 14.7)[b]
Platinum dusts or fumes	1.3 (0.30, 5.5)	1.6 (0.06, 3.1)	2.9 (0.69, 12.4)	4.9 (3.2, 6.6)[b]
Stainless steel (Chromium dusts or fumes)	1.5 (0.84, 2.8)	1.8 (0.95, 3.4)	2.7 (1.5, 4.9)[b]	3.0 (1.6, 5.7)[b]
Miscellaneous Exposures				
Acids (muriatic, sulfuric)	1.4 (0.85, 2.4)	1.4 (0.83, 2.4)	1.6 (0.98, 2.7)	1.7 (1.0, 2.9)[b]
Alkali (caustics, lye, sodium hydroxide)	1.4 (0.73, 2.7)	1.3 (0.66, 2.1)	2.1 (1.1, 3.9)[b]	2.1 (1.0, 4.1)[b]
Animals (fur/wastes)	1.8 (1.1, 2.8)[b]	1.9 (1.2, 3.1)[b]	1.5 (0.96, 2.3)	1.6 (1.0, 2.6)[b]
Concrete form oils	1.4 (0.81, 2.3)	1.4 (0.81, 2.4)	1.9 (1.1, 3.1)[b]	2.0 (1.2, 3.4)[b]
Enzymes (detergent, plastic, or pharmaceutical industry)	1.8 (0.96, 3.3)	2.0 (1.1, 3.9)[b]	2.0 (1.1, 3.7)[b]	2.2 (1.1, 4.2)[b]
Exhaust from engines	0.92 (0.54, 1.6)	1.0 (0.57, 1.8)	1.9 (1.1, 3.3)[b]	2.0 (1.1, 3.7)[b]
Fumes from heated plastics	1.2 (0.71, 2.2)	1.4 (0.77, 2.5)	1.6 (0.94, 2.8)	1.8 (1.0, 3.3)[b]
Mold	1.8 (1.1, 2.9)[b]	2.0 (1.2, 3.3)[b]	2.3 (1.4, 3.6)[b]	2.4 (1.5, 4.0)[b]
Printing inks and oils	1.7 (0.71, 4.0)	2.3 (0.90, 5.9)	3.4 (1.4, 8.2)[b]	5.1 (1.8, 14.9)[b]
Styrene	1.7 (0.91, 3.2)	1.7 (0.89, 3.3)	1.9 (1.1, 3.7)[b]	1.9 (1.0, 3.7)[b]
Urethane foam insulation	1.5 (0.93, 2.3)	1.4 (0.88, 2.2)	1.7 (1.1, 2.7)[b]	1.8 (1.1, 2.8)[b]

[a]Adjusted for age, sex, time in the union, and ever smoking history.
[b]Significant at 0.05 level.

diagnosis of asthma between our last observation of claims in December 1992, and the time when the questionnaires were mailed in the spring of 1995. This would result in the misclassification of cases as controls, and could explain some of the differences in classification of cases between the two case definitions.

We tested the importance of a large number of exposures, many of which overlapped. When so many exposures overlap, this makes it difficult to identify clearly the offending agent(s), and we could not realistically assess the interaction of multiple exposures.

CONCLUSIONS

These analyses demonstrated ways that combined administrative data, including health insurance and workers' compensation claims, can be utilized for epidemiologic research. These include methods of internal analyses which allow the use of all data up until censorship. Sources of external comparison were explored including the Occupational Supplement to the NHIS and SEER Program data. External referent population comparisons are needed to study possible occupational lung disorders which might affect a high proportion of carpenter subpopulations. Using internal comparisons alone under these circumstances would tend to underestimate some risks.

These data, using health insurance claims, could also be used for comparisons to other worker groups. Studies of other worker groups, using similar methods of combining data from private and workers' compensation insurance, could provide useful comparisons and may give better insight into which groups are at greater risk of work-related lung diseases.

Through the use of these combined data sources, we were also able to define a clear study base which could be used for nested case-control analyses—an important principle to adhere to in order to get unbiased results in case control studies [Wacholder et al., 1992]. Although this work does not establish causal relationships, a number of the additional exposures which were associated with asthma using Burney's definition are ones to which a majority of these carpenters were exposed. These included cement, drywall, demolition, and silica dusts; caulks; concrete form oils; and exhaust from engines. If these common exposures cause asthma or aggravate existing cases of asthma among these carpenters and appropriate systems of control are put in place, the potential for prevention is great. Further work is needed to clearly define which of these agents cause or aggravate asthma and to explore possible interactions. Such studies should focus on new and existing cases of asthma with concurrent measurements of exposures of interest identified from this study. This research also has identified possible exposures among carpenters which should be addressed through hazard surveillance studies, which measure exposure levels and frequency of exposure.

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REFERENCES

ATSDR 1993 (Unpublished): Study of symptom and disease prevalence, Caldwell Systems Inc. hazardous waste incinerator, Caldwell County, North Carolina.

Bakke P, Hanoa R, Gulsvik A (1992): Obstructive lung disease in a Norwegian population group—risk factors and occurrence (English abstract). Tidsskrift for Den Norske Laegeforening 112:2836–2840.

Bernacki EJ, Tsai SP (1989): Use of group health insurance claims data to assess morbidity among employed persons. J Occup Med 31:677–678.

Bernacki EJ, Tsai SP, Reedy SM (1986): Analysis of a corporation's health care experience: implications for cost containment and disease prevention. Corporate Health Care 28:502–508.

Blessman JE (1991): Differential treatment of occupational disease vs. occupational injury by workers' compensation in Washington State. J Occup Med 33:121–126.

Blose JO, Holder HD (1991): Injury-related medical care utilization in a problem drinking population. Am J Public Health 81:1571–1575.

Bond GG, Ott MG, Brenner FE, Cook RR (1983): Medical morbidity surveillance findings among employees potentially exposed to TCDD. Br J Ind Med 40:318–324.

Burney PGJ, Chinn S (1987): Developing a new questionnaire for measuring the prevalence and distribution of asthma. Chest 91 (suppl):79S–83S.

Burney PGJ, Chinn S, Britton JR, Tattersfield AE, Papacosta AO (1989): What symptoms predict the bronchial response to histamine? Evaluation in a community survey of The Bronchial Symptoms Questionnaire (1984) of the International Union Against Tuberculosis and Lung Disease. Int J Epidemiol 18:165–173.

Chan-Yeung M (1990): Occupational asthma. Chest 98:148S–161S.

Checkoway H, Pearce N, Crawford-Brown D (1989): Cohort studies. In Checkoway H, Pearce N, Crawford-Brown D (eds): ‘‘Research Methods in Occupational Epidemiology.’’ New York: Oxford University Press, pp 125–128.

Checkoway H, Pearce N, Dement JM (1989): The design and conduct of occupational epidemiology studies: Part IV. The analysis of case-control data. Am J Ind Med 15:403–415.

Courteau J, Cushman R, Bouchard F, Quevillon M, Chartrand A, Bherer L (1994): Survey of construction workers repeatedly exposed to chlorine over a three to six month period in a pulpmill: I. Exposure and symptomatology. Occup Environ Med 51:219–224.

Daugbjerg P (1989): Is particle board in the home detrimental to health? Environ Res 48:154–163.

Dean AG, Dean JA, Coulombier D, Burton AH, Brendel KA, Smith DC, Dicker RC, Sullivan KM, Fagan RF (1994): ‘‘EpiInfo, Version 6: A Word Processing, Database, and Statistics Program for Epidemiology on Microcomputers.’’ Atlanta, Ga: Centers for Disease Control and Prevention.

Department of Health, Education and Welfare (1980): Occupational mortality in the State of California, 1959–61; Petersen GR, Milham S. U.S. Department of Health, Education and Welfare, DHEW(NIOSH) Publication No. 80–104.

Ferris BG (1978): Epidemiology standardization project. Am Rev Respir Dis 118:1–53.

Firth HM, Herbison GP, Cooke KR, Fraser J (1993): Male cancer mortality by occupation: 1973–86. New Zealand Med J 106:328–330.

Fischbein A, Luo HC, Lacher M, Rosenfeld S, Rosenbaum A, Miller A, Solomon SJ (1993): Respiratory findings among millwrights and machinery erectors: identification of health hazards from asbestos in place at work. Environ Res 61:25–35.

Franklin GM, Haug J, Heyer N, Checkoway H, Peck N (1991): Occupational carpal tunnel syndrome in Washington State, 1984–1988. Am J Public Health 81:741–746.

Garcia-Closas M, Christiani DC (1995): Asbestos-related diseases in construction carpenters. Am J Ind Med 27:115–125.

Heederik D, Kromhout H, Burema J, Biersteker K, Krohout D (1990): Occupational exposure and 25-year incidence rate of non-specific lung disease: the Zutphen study. Int J Epidemiol 19:945–952.

Hessel PA, Herbert A, Melenka LS, Yoshida K, Michaelchuk MA, Nakaza M (1995): Lung health in sawmill workers exposed to pine and spruce. Chest 108:642–646.

Hunting KL, Welch LS (1993): Occupational exposure to dust and lung disease among sheet metal workers. Br J Ind Med 50:432–442.

International Agency for Research on Cancer (February, 1991): ‘‘IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans: Wood, Leather and Some Associated Industries.’’ Lyon, France: World Health Organization, WHO Vol. 25.

Kanerva L, Jolanki R, Toikkanen J (1994): Frequencies of occupational allergic diseases and gender differences in Finland. Int Arch Occup Environ Health 66:111–116.

Kleinbaum D, Kupper L, Mueller K (1988): Maximum likelihood methods: theory and applications. In Kleinbaum, Kupper, Mueller (eds.): ‘‘Applied Regression Analysis and Other Multivariate Methods, Second Ed.’’ Boston: PWS-Kent Publishing Co., pp 497–512.

Kleinbaum D, Kupper L, Morgenstern H (1982): Chapter 12: Information Bias. In: ‘‘Epidemiologic Research: Principles and Quantitative Methods.’’ New York: Van Nostrand Reinhold, pp 222–223.

Lemeshow S, Hosmer DW (1984): Estimating odds ratios with categorically scaled covariates in multiple logistic regression. Am J Epidemiol 119:147–151.

Malo J, Cartier A, Desjardins A, Weyer R, Vandenplas O (1995): Occupational asthma caused by oak wood dust. Chest 108:856–858.

Malo JL, Cartier A, L’Archevaque J, Trudeau C, Courteau J, Bherer L (1994): Prevalence of occupational asthma among workers exposed to eastern white cedar. Am J Respir Crit Care Med 150:1697–1701.

Mathias CGT, Sinks TH, Seligman P, Halperin WE (1990): Surveillance of occupational skin diseases: a method utilizing worker’s compensation claims. Am J Ind Med 17:363–370.

Meredith SK, Taylor VM, McDonald JC (1991): Occupational respiratory disease in the U.K. 1989: a report to the British Thoracic Society of Occupational Medicine: the SWORD project group. Br J Ind Med 48:292–298.

National Institute for Occupational Safety and Health (July, 1974): Mortality experience of the AFL-CIO Brotherhood of Carpenters and Joiners of America, 1969–1970; Milham, S. Salt Lake City, UT: U.S. Department of Health, Education and Welfare, HEW (NIOSH) Publ No. 74–129.

National Institute for Occupational Safety and Health (1991): Work-Related Lung Disease Surveillance Report, U.S. Department of Health and Human Services, (NIOSH) Publ No. 91–113.

National Institute of Occupational Safety and Health (1992): Work-Related Lung Disease Surveillance Report Supplement 1992, U.S. Department of Health and Human Services, (NIOSH) Publ No. 91–113S.

National Institute of Occupational Safety and Health (1996): Work-Related Lung Disease Surveillance Report, U.S. Department of Health and Human Services, (NIOSH) Publ No. 96–134.

Nelson DE, Emont SL, Brackbill RM, Cameron LL, Peddicord J, Fiore MC (1994): Cigarette smoking prevalence by occupation in the United States; a comparison between 1978–1980 and 1987–1990. J Occup Med 36:516–524.

Norrish AE, Beasley R, Hodgkinson EJ, Pearce N (1992): A study of New Zealand wood workers; exposure to wood dust, respiratory symptoms, and suspected cases of occupational asthma. New Zealand Med J 105:185–187.

Ng TP, Hong CY, Goh LG, Wong Ml, Koh KTC (1994): Risks of asthma associated with occupations in a community-based case-control study. Am J Ind Med 25:709–718.

Pearce N, Checkoway H, Dement J (1988): Exponential models for analyses of time-related factors, illustrated with asbestos textile worker mortality data. J Occup Med 30:517–522.

Pell S (1989): Health insurance claims as a source of morbidity data, DuPont Company’s experience (commentary). J Occup Med 31:679–680.

Pell S, Fayerweather WE (1985): Trends in the incidence of myocardial infarction and in associated mortality and morbidity in a large employed population, 1957–1983. N Eng J Med 312:1005–1011.

Rautiala S, Reponen T, Hyvarinen A, Nevalainen A, Husman T, Vehvilainen A, Kalliokoski P (1996): Exposure to airborne microbes during the repair of moldy buildings. Am Indus Hyg J 57:279–284.

Reilly MJ, Rosenman KD, Watt F, Schill D, Stanbury M, Trimbath LS, Jajosky RAR, Musgrave KJ, Castellan RM, Bang KM, Ordin DL (June 10, 1994): Surveillance for Occupational Asthma—Michigan and New Jersey, 1988–1992. MMWR 43 (No. SS-1):9–17.

Rijcken B, Schouten JP, Mensinga TT, Weiss ST, De Vries K, Van der Lende R (1993): Factors associated with bronchial hyper-responsiveness to histamine in a population sample of adults. Am Rev Respir Dis 147 (6 Pt 1):1447–53.

Ries LAG, Miller BA, Hankey BF, Kosary CL, Harras A, Edwards BK (eds)(1994): ‘‘SEER Cancer Statistics Review, 1973–1991: Tables and graphs.’’ Bethesda, MD: National Cancer Institute. National Institutes of Health, Publ No. 94-2789.

Robinson C, Stern F, Halperin W, Venable H, Petersen M, Frazier T, Burnett C, Lalich N, Salg J, Sestito J, Fingerhut M (1995b): Assessment of mortality in the construction industry in the U.S., 1984–1996. Am J Ind Med 28:49–70.

Robinson CF, Petersen M, Sieber WK, Palu S, Halperin WE (1997): Mortality of carpenters’ union members employed in the U.S. construction or wood products industries, 1987–1990. Am J Ind Med 30:674–694.

Robinson CF, Halperin WE, Alterman T, Braddee RW, Burnett C, Fosbroke DE, Kisner SM, Lalich NR, Roscoe RJ, Seligman PJ, Sestito JP, Stern FB, Stout NA (April, 1995a): Mortality patterns among construction workers in the U.S. Occup Med: State of the Art Reviews 10:269–283.

SAS Institute, Inc.: ‘‘The SAS System, Version 6.10.’’ Cary, NC: SAS Institute, Inc.

Schenker MB, Gold EB, Lopez RL, Beaumont JJ (1993): Asthma mortality in California, 1960–1989. Demographic patterns and occupational associations. Am Rev Respir Dis 147:1454–1460.

Séguin P, Allard A, Carier A, Malo JL (1987): Prevalence of occupational asthma in spray painters exposed to several types of isocyanates, including polymethylene polyphenylisocyanates. J Occup Med 29:340–344.

Siracusa A, Kennedy SM, DyBuncio A, Lin FJ, Marabini A, Chan-Yeung M (1995): Prevalence and predictors of asthma in working groups in British Columbia. Am J Ind Med 28:411–423.

Statistics and Epidemiology Research Corporation (1991): ‘‘Epidemiological Graphics, Estimation, And Testing Package. Analysis Model (PECAN), Version 0.26.6.’’ Seattle, WA: Statistics and Epidemiology Research Corp.

Stellman SD, Garfinkel L (1984): Cancer mortality among woodworkers. Am J Ind Med 5:343–357.

Tanaka S, Seligman P, Halperin W, Thun M, Timbrook MA, Wasil JJ (1988): Use of workers’ compensation claims data for surveillance of cumulative trauma disorders. J Occup Med 30:488–492.

U.S. Department of Health and Human Services, Public Health Services, Centers for Disease Control and Prevention (July 1993): Health conditions among the currently employed: U.S., 1988:32.

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Health Statistics (reissued December 1994): 1988 National Health Interview Survey, CD-ROM Series 10, No. 2, SETS Version 1.22.

U.S. Department of Health and Human Services, Public Health Services, Centers for Disease Control and Prevention, National Center for Health Statistics (March 1995): 1990 National Ambulatory Medical Care Survey. CD-ROM Series 13, No. 3.

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Health Statistics (October 1995): 1992 National Ambulatory Medical Care Survey. CD-ROM Series 13, No. 4.

Van Peenen PFD, Blanchard AG, Wolonsky PM, Gill TM (1986): Health insurance claims of petrochemical company employees. J Occup Med 28:237–240.

Vandenplus O, Cartier A, Lesage J, Perrault G, Grammer LC, Malo JL (1992): Occupational asthma caused by a pre-polymer but not monomer of toluene diisocyanate. J Allergy Clin Immunol 89:1183–1188.

Vilkman S, Keistinen T, Tuuponen T, Kivela SL (1996): Age distribution of patients treated in hospital for chronic obstructive pulmonary disease. Age and Aging 25:109–112.

Wang ZP, Larsson K, Malmberg P, Sjorgen B, Hallberg B, Wrangskogk K (1994): Asthma, lung function and bronchial responsiveness in welders. Am J Ind Med 26:741–754.

Wacholder S, McLaughlin JK, Silverman DT, Mandel JS (1992): Selection of controls in case-control studies. I. Principles. Am J Epidemiol 135(9): 1019–1028.

Weislander G, Janson C, Norback D, Bjornsson E, Stalenheim G, Edling C (1994): Occupational exposure to water-based paints and self-reported asthma, lower airway symptoms, bronchial hyperresponsiveness, and lung function. Int Arch Occup Environ Health 66:261–267.

White MC, Baker EL (1988): Measurement of respiratory illness among construction painters. Br J Ind Med 45:523–531.

Zahm SH, Brownson JC, Chang JC, Davis JR (1989): Study of lung cancer histologic types, occupation and smoking in Missouri. Am J Ind Med 15:565–578.