Proportionate Mortality Study of the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry

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Background *This study examined causes of deaths among unionized plumbers, pipefitters and allied trades.*
Methods *Deaths of union members from the years 1971, 1979, 1987, and 1995 were selected as a representative sample from a computer file provided by the union. These years provided 15,411 deaths for proportionate mortality ratio (PMR) analysis.*
Results *PMRs for lung cancer and asbestosis were significantly elevated compared to U.S. white males. PMRs for chronic disease of the endocardium and cardiomyopathy were also elevated. Elevations were not observed in other a priori causes: laryngeal cancer, lymphatic cancer, and neurological disorders. PMRs for transportation accidents for pipe/steam-fitters were elevated in 1971 and 1979, but not in 1987 or 1995.*
Conclusion *Despite the limitations of a PMR analysis, study results indicate mortality related to asbestos exposure is, and will continue to be, an area of concern for members of the union.* Am. J. Ind. Med. 51:950–963, 2008. *Published 2008 Wiley-Liss, Inc.*[†]

KEY WORDS: construction; plumber; pipe-fitter; sprinkler-fitter; asbestos

INTRODUCTION

The composition and purpose of the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada (UA) has been described previously [Kaminski et al., 1980; Finkelstein and Verma, 2004]. Briefly, the UA, an affiliate of the AFL/CIO, has been in existence since 1889 and is currently one of the largest international trade unions in North America with over 300,000 members. The original name of the UA was the United Association of Journeymen Plumbers, Gas Fitters, Steam Fitters and Steam Fitters' Helpers of the United States and Canada. Trade designations recognized by the UA have changed over the years. For example, the steamfitter classification was responsible for the installation of steam heating systems and all other piping. But as technology and heating systems changed, the broader classification of "pipefitter" was officially recognized by the UA in 1947 and the steamfitter and pipefitter trades are now virtually synonymous. The UA currently recognizes five main trade designations: plumbers, pipefitters, sprinklerfitters, HVAC (heating, ventilation, air conditioning) techs, and welders.

UA members are involved in a wide variety of workplaces and work situations (e.g., new construction worksites, nuclear plants, shipyards, power plants, chemical refineries, and gas pipeline installation and repair) and are exposed to many chemical compounds. These exposures may be episodic in nature. A survey conducted during 1981–1983 among a representative sample of 4,500 U.S. industrial facilities employing nearly 1.8 million workers found that plumbers and pipefitters were potentially exposed to toxic agents including acrylonitrile, asbestos, benzene, beryllium, cadmium, chromium, lead, nickel, styrene-butadiene rubber,

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manganese, and vinyl chloride [NIOSH, 1983]. Other studies have reported additional workplace exposures: plumbers in residential construction to zinc chloride, ammonium chloride, tin, antimony, copper, silver, and methyl ethyl ketone [Methner et al., 2000]; plumbers and steamfitters to arsenic [NIOSH, 1996]; pipefitters to terahydrofuran, dimethylformamide, and cyclohexane [NIOSH, 1984]; and plumbers to carbon monoxide and smoke [Hunting et al., 1999]. Recently published reports implicate manganese, an element commonly used in welding processes, as a possible cause for a neurologic syndrome similar to Parkinson's disease [Dobson et al., 2004; Olanow, 2004].

The purpose of this study is to examine the proportionate mortality of a sample of deceased UA members from the United States and identify elevated causes of death. This identification will assist in the appropriate targeting of future health and safety interventions undertaken by the union and by other safety and health organizations. Based on the presumed exposures, a priori causes of death to be examined in this cohort include lung cancer, laryngeal cancer, lymphatic cancer, neurological disorders, asbestosis, mesothelioma, and non-malignant respiratory diseases.

METHODS AND MATERIALS

Study Population and Study Sample

The UA has maintained a computerized membership file since 1967. That file contains fields for name, Social Security number, date of birth, date of initiation into the union, trade, death claim data, dates for which dues were paid and limited local affiliation information. The members included in that file were paying union dues at the time of their death, whether they were currently employed, unemployed or retired. The UA estimated that a large majority of retirees continued to pay union dues even after they stopped working in order to retain entitlement to the UA death benefit for their survivors (Personal communication, William C. Rhoten, UA Director of Safety and Health, March 1, 2004).

The UA provided NIOSH with a copy of the electronic master file which contained 116,005 deaths. Although information was available for deaths as early as 1929, the file is only considered complete for 113,566 deaths during the period 1976–2001. The file did not contain race or gender information. Canadian union members were included in the master file but were excluded from all analysis since this study used U.S. mortality proportions.

Since it was not cost effective to validate and analyze such a large number of deaths, it was determined that a sample of deaths from four separate years would still provide statistically valid results. Coded death and membership data from the year 1971 were already available from the Kaminski study. Deaths from the years 1979, 1987, and 1995 were added to account for possible temporal differences in workplace exposures and concurrent patterns of proportionate mortality for selected causes of death. There were no indications that deaths in the selected years would exhibit any unusual patterns or would not be representative of the entire time period. The number of deaths from these 4 years provided adequate statistical power to examine even relatively rare causes-of-death.

The UA master file contained member information for 13,134 deaths in the years 1979, 1987, and 1995. Exclusion criteria included belonging to non-U.S. locals (n = 806), non-U.S. death (n = 34), date of death outside the study period (n = 27), unknown cause of death (n = 240), or missing date of birth (n = 14). Kaminski analyzed 3,369 UA deaths in 1971. The current study included 48 deaths that were excluded by Kaminski (one death that occurred prior to 20 years of age and 47 deaths of unknown race) and excluded 19 deaths missing date of birth, resulting in a total of 3,398 deaths from 1971. Therefore 15,411 deaths were available for analysis for 1971, 1979, 1987, and 1995 (Table I).

TABLE I. Sample Size and Death Ascertainment

Source	Deaths
UA masterfile	
UA death benefit claims for 1979, 1987, and 1995	13,134
Exclude if	
Associated with a non-U.S. local	−806
Death outside of the United States	−34
Verified date of death outside study period	−27
Cause of death not available[a]	−240
Missing date of birth	−14
Available for analysis	12,013
Kaminski et al. [1980]	
UA death benefit claims for 1971	3,794
Exclude if	
Death outside of the United States	−194
Death certificate not available	−119
Missing date of birth	−19
Non-white race	−64
Available for analysis	3,398[b]
Combined	
Total available for analysis	15,411

[a]Cause of death information was not available via NDI for 391 deaths. For these, death certificates were requested first from the UA and then from the state of death (if known). A total of 151 death certificates were located using this method.

[b]This number (3,398) differs slightly from the number (3,369) reported in Kaminski et al. [1980] since (i) Kaminski et al. excluded 1 death based on age and 47 deaths of unknown race which were included (and assumed white) in the present analysis and (ii) Kaminski et al. included 19 workers with missing dates of birth which were excluded in the present analysis.

Death Ascertainment and Cause of Death Coding

For the deaths occurring in 1971, death certificates were procured from state vital statistics offices. Causes of death were coded by a nosologist utilizing the International Classification of Diseases (ICD) revision in effect at the time of death. The National Death Index (NDI) Plus service, provided by the National Center for Health Statistics, contains coded causes of death for all deaths occurring in the United States after 1978. NDI Plus was used to obtain underlying and contributing cause of death codes for deaths occurring in 1979, 1985, and 1995. Although the NIOSH NDI-match program is highly effective in obtaining all available deaths from the NDI, it has been found that 3–5% of known deaths cannot be obtained from the NDI for various reasons, usually due to erroneous information provided by the informants on death certificates [Calle and Terrell, 1993]. In these cases, death certificates were requested from the UA, if available, and then from state vital statistics offices. Causes of death were coded by a nosologist utilizing the ICD revision in effect at the time of death.

Since a specific code for mesothelioma did not exist prior to the ICD 10th revision, which began in 1999, hardcopy death certificates were obtained to identify mesothelioma deaths. Death certificates were requested if NDI supplied one of the following ICD-9 underlying cause of death codes associated with mesothelioma: (1) malignant neoplasms of the peritoneum and other and unspecified of digestive organs (ICD-9 codes 158–159), (2) malignant neoplasms of other parts of the respiratory system (ICD-9 codes 160, 163–165), (3) malignant neoplasms of other and unspecified sites (ICD-9 codes 187, 194–199), and (4) other benign and unspecified nature neoplasms (ICD-9 codes 210–223, 226–237.4, 238–239.5).

Trade Designation

For members who died in 1971, trade designations identified by Kaminski were used. For members who died in 1979, 1987, and 1995, the UA master file contained division, trade, and skill codes which were collapsed into nine trade designations: lead burner, metal trades, pipe/steam-fitter, pipe/steam-fitter–refrigeration, pipe/steam-fitter–residential, plumber, plumber–residential, sprinkler fitter, and ‘‘other’’. Since the number of deaths for several of the categories was very small, trade codes were further collapsed into the following trade groupings: plumber (including residential plumbers), pipe/steam-fitter (including residential and refrigeration pipe/steam-fitters), metal trades, sprinkler fitter, lead burner and other (Table II). Deceased members in the lead burner and other trades totaled less than 1% of the total deaths and were not included in trade-specific analysis. These members were included in analysis for the entire sample. A majority of the members (93%) were associated with a single trade. Members associated with more than one trade group were assigned to a ‘‘mixed’’ trade group and were not included in trade-specific analysis.

Statistical Analysis

Proportionate mortality ratio (PMR) analysis was conducted using the NIOSH Life Table Analysis System (LTAS) [Steenland et al., 1990, 1998]. The PMR methodology was used in lieu of the standardized mortality ratio (SMR), which estimates the risk of mortality, because information on the entire population at risk was not known. The number of deaths in the study population, by underlying cause, was compared to the number of deaths expected. Expected deaths were based on mortality proportion files available with the NIOSH LTAS which include proportions

TABLE II. Distribution of Trade Group for UA Deaths (1971, 1979, 1987, and 1995) by Year of Death and Overall

	Year of death				
Trade	1971	1979	1987	1995	Total
Plumbers	1,367 (40%)[a]	1,296 (34%)	1,361 (33%)	1,392 (34%)	5,416 (35%)
Pipe/steam-fitters	1,869 (55%)	2,006 (52%)	2,110 (51%)	1,991 (49%)	7,976 (52%)
Metal trades	98 (3%)	210 (5%)	215 (5%)	166 (4%)	689 (4%)
Sprinkler fitters	54 (2%)	93 (2%)	92 (2%)	96 (2%)	335 (2%)
Lead burner	8 (<1%)	8 (<1%)	3 (<1%)	3 (<1%)	22 (<1%)
Other and unknown	2 (<1%)	8 (<1%)	6 (<1%)	11 (<1%)	27 (<1%)
Mixed[b]	—	229 (6%)	318 (8%)	399 (10%)	946 (6%)
Total	3,398	3,850	4,105	4,058	15,411

[a]Number in parentheses is percent of deaths associated with trade group among all deaths in the given year.
[b]For deaths in 1979, 1987, and 1995, "mixed" denotes UA members who were associated with more than one trade group (e.g., a member with experience as a plumber and as a pipe-fitter). This information was not available for the 1971 deaths.

for the U.S. white male population for the 5-year calendar-time periods beginning with 1960 and ending with 1995–1999, and by 5-year age groups from 15 to 19 years through 80–84 years and then for 85 years and older. Consequently the 1970–1974, 1975–1979, 1985–1989, and 1995–1999 calendar periods were used for UA deaths occurring in 1971, 1979, 1987, and 1995, respectively. Although race and sex information was not provided by the UA, white male mortality rates were used based on discussions with the UA and a manual review of a sample of 700 death certificates (98% of which indicated ''white'' or Caucasian race and 99% of which specified male). PMRs were calculated by dividing the observed number of deaths by the expected number of deaths. Statistical significance of the results was determined using the Poisson distribution and 95% confidence intervals (CIs). When the observed number of deaths was greater than or equal to six, the Byar approximation to the exact test was used; when the observed number of deaths was less than six, exact confidence limits were used [Rothman and Boice, 1979].

Results were stratified by trade designation and by year of death (1971, 1979, 1987, 1995) to identify possible trade or time specific differences that may have affected proportionate mortality. Results could not be stratified by actual duration of employment since the UA master file did not include dates of first and last employment or retirement dates; however, results were stratified by an estimated duration of employment (<20, 20–29, 30+ years) beginning with the date members were initiated into UA membership and ending with an assumed retirement date when the members reached age 60. In this analysis, only deaths with 20 years of more of potential latency were considered. Local and job-specific analysis could not be conducted since reliable job classification and local affiliation data were only available for some UA members.

Proportionate mortality from Parkinson's and other neurological diseases was evaluated using custom proportion files that were created using previously existing methods [Steenland et al., 2006].

A multiple-cause-of-death analysis that uses all causes-of-death as coded on the death certificate was conducted to examine any disease excesses not identified using only underlying causes-of-death [Steenland et al., 1992]. This analysis includes the usual underlying cause of death as well as contributory causes and other significant conditions at time of death which the physician or other medical provider noted on the death certificate and compares these results with those expected using multiple cause of death referent rates. Good candidates for multiple cause analysis are diseases which are of long duration, not necessarily fatal, yet serious enough to be noted on the death certificate.

A direct assessment of the effect of smoking patterns on proportionate mortality results was not possible since information on the smoking habits of the cohort was not available.

Proportionate cancer mortality ratio (PCMR) analysis are often conducted to correct for possible biases in the cancer mortality PMR due to elevations or deficits from other non-malignant causes, particularly a possible deficit of deaths from heart disease due to the ''healthy worker effect'' [McMichael, 1976; Walter, 1986; Sterling and Weinkam, 1986]. A PCMR is the ratio of the observed cancer deaths to expected cancer deaths, where the expected cancer deaths are calculated based on the proportion of cause-specific cancers among all cancer deaths, rather than all deaths as is done in PMR analysis. There are counter-balancing limitations to the PCMR. Most significantly, when there is an elevated cancer risk in a ''non-rare'' cancer, such as lung cancer, the PCMR will not adequately represent the true cancer mortality risk [Wong et al., 1985; Walter, 1986]. Since elevated proportionate mortality from lung cancer was expected in our cohort due to asbestos exposures and based on the results of the Canadian UA members, the utility of a PCMR calculation would be limited and the PCMR analysis was not conducted.

RESULTS

Table III provides key characteristics of the final cohort analyzed. The median age of entry into the union dropped from 34.2 years of age for deaths in 1979 to 30.7 years for deaths in 1995. The median age at death for cohort members steadily increased: 65 years in 1971, 68.2 in 1979, 72.2 in 1987 and 75.5 in 1995. The deceased UA members were evenly distributed throughout the four regions of the United States.

Table IV provides observed deaths and PMRs for all trades combined with a subgroup analysis for the plumber and pipe/steam-fitter trade designations. Table V presents selected causes of death, by year of death and by major trade. Table VI provides observed deaths and PMRs by estimated duration of employment for deaths with 20 years or more of potential latency.

A Priori Cause of Death Results

Proportionate mortality for ''all cancers'' was elevated for the entire sample (PMR = 1.15, CI: 1.11–1.18), for plumbers (PMR = 1.18, CI: 1.12–1.24) and for pipe/steam-fitters (PMR = 1.12, CI: 1.07–1.17). Overall cancer proportionate mortality was relatively level across the 4 years, with slightly declining proportionate mortality noted among plumbers. The elevation was highest among cohort members that had 20 years or more of estimated employment.

Lung cancer PMRs were significantly elevated for the entire sample (PMR = 1.29, CI: 1.23–1.35) and for both

TABLE III. Characteristics of the UA Deaths (1971, 1979, 1987, and 1995) by Year of Death and Overall

	Year of death				
Characteristic	**1971**	**1979**	**1987**	**1995**	**Total**
Age at initiation[a], years					
Median	N/A	34.2	32.8	30.7	32.3
Range		16–71	15–65	15–65	15–71
Years since initiation[a]					
Median	N/A	31.6	37.9	43.5	37.2
Range		0.1–72	0.6–76	0.3–76	0.1–76
<20 years		526 (18%)	388 (12%)	177 (5%)	1,091 (11%)
20–29 years		753 (25%)	390 (12%)	462 (14%)	1,605 (17%)
30–39 years		1,244 (42%)	1,174 (36%)	585 (18%)	3,003 (32%)
40+ years		465 (16%)	1,279 (40%)	2,072 (63%)	3,816 (40%)
Age at death, years					
Median	65.0	68.2	72.2	75.5	70.7
Range	19–104	20–99	22–101	19–105	19–105
Region of United States[b]					
Northeast	N/A	897 (23%)	944 (23%)	852 (21%)	2,693 (22%)
South		1,037 (27%)	1,175 (29%)	1,155 (28%)	3,367 (28%)
Midwest		1,112 (29%)	1,126 (27%)	1,197 (29%)	3,435 (29%)
West		803 (21%)	860 (21%)	852 (21%)	2,515 (21%)
Unknown		1 (<1%)	0 (0%)	2 (<1%)	3 (<1%)

N/A, not available.
[a]Limited to UA members with initiate status at death (n = 9,515).
[b]Region of United States based on assigned UA local at death.

plumbers (PMR = 1.32, CI: 1.21–1.43) and pipe/steam-fitters (PMR = 1.25, CI 1.17–1.34). The PMRs were elevated in both trades for each of the four years analyzed. Elevated lung cancer PMRs were observed in all three categories of estimated duration of employment.

Laryngeal cancer was elevated, but not significantly, in the plumber (PMR = 1.12), pipe/steam-fitters (PMR = 1.41) and combined analysis (PMR = 1.28). There were no clear patterns to these elevations by year of death. PMR results ranged from 0.54 in 1995 to 1.57 in 1979 among plumbers and from 0.66 in 1971 to 2.36 among pipe/steam-fitters in 1987. The overall number of laryngeal cancer deaths for this cohort was small: 57. The laryngeal cancer PMR was significantly elevated among cohort members with 30 years or more of estimated employment.

Elevated numbers of cancers of the lymphatic and hematopoietic systems have been noted in other studies of plumbers and pipefitter cohorts, but no consistent elevations were detected in this study. Plumbers may have experienced elevated proportionate mortality at one time (1971 PMR = 1.44) but there is no indication that the elevation persisted (combined plumber PMR = 1.14).

Proportionate mortality from Parkinson's disease was lower than expected in analysis of the plumber (PMR = 0.76) and pipe/steam-fitter (PMR = 0.84) trades and in the combined analysis (PMR = 0.78). Analysis by year of death demonstrated generally a consistent pattern of reduced proportionate mortality in both trades.

Proportionate mortality from non-malignant diseases of the respiratory system was not elevated in analysis of the plumber (PMR = 0.95), pipe/steam-fitter (PMR = 1.05) trades or in the combined analysis (PMR = 1.00); however, asbestosis was highly elevated for the entire cohort (PMR = 11.07, CI: 7.62–15.55), largely driven by the pipe/steam-fitter sub-cohort (PMR = 17.55, CI: 11.56–25.53). For pipe/steam-fitters, asbestosis demonstrated strongly increasing proportionate mortality across the years sampled. While no asbestosis deaths were reported in 1971, significantly elevated, and increasing, proportionate mortality was noted for 1979 (PMR = 13.49), 1987 (PMR = 16.65), and 1995 (PMR = 20.77). No plumbers died from asbestosis in 1971 and 1979 while two died from asbestosis in 1987 and two in 1995. The asbestosis PMR was significantly elevated among cohort members with more than 20 years of estimated employment.

Cancers of "other parts of the respiratory system" (PMR = 3.32, CI: 2.42–4.44) and "other and unspecified sites" (PMR = 1.40, CI: 1.25–1.56) were elevated. As

TABLE IV. Proportionate Mortality (Reference U.S.White Male Deaths) for UA Deaths (1971, 1979, 1987, and 1995) Among Plumbers, Pipe/Steam-Fitters and All Trades Combined

	Plumbers			Pipe/steam-fitters			All trades combined		
Underlying cause of death	**OBS**	**PMR**	**95% CI**	**OBS**	**PMR**	**95% CI**	**OBS**	**PMR**	**95%**
All deaths	5,416	1.00		7,976	1.00		15,411	1.00	
All cancers	1,488	1.18**	1.12–1.24	2,126	1.12**	1.07–1.17	4,185	1.15**	1.11–1.18
MN of buccal cavity and pharynx	37	1.29	0.91–1.78	48	1.08	0.80–1.44	93	1.10	0.89–1.35
MN of digestive organs and peritoneum	350	1.10	0.99–1.22	480	1.01	0.92–1.10	946	1.03	0.97–1.10
MN of esophagus	40	1.29	0.92–1.76	57	1.22	0.92–1.58	111	1.22*	1.00–1.47
MN of stomach	55	1.28	0.96–1.66	72	1.12	0.88–1.41	148	1.21*	1.02–1.42
MN of intestine, except rectum	127	1.07	0.89–1.27	176	0.99	0.85–1.15	344	1.01	0.90–1.12
MN of rectum	31	1.15	0.78–1.63	40	1.00	0.71–1.36	80	1.05	0.83–1.30
MN of biliary passages, liver and gall bladder	20	0.92	0.56–1.42	29	0.89	0.60–1.28	57	0.90	0.68–1.17
MN of liver, not specified	13	1.47	0.78–2.51	12	0.91	0.47–1.59	27	1.06	0.70–1.55
MN of pancreas	58	0.92	0.70–1.19	91	0.95	0.77–1.17	169	0.92	0.79–1.07
MN of peritoneum and other and unspecified	6	1.31	0.48–2.86	3	0.44	0.09–1.28	10	0.76	0.36–1.40
MN of respiratory system	591	1.32**	1.22–1.43	881	1.29**	1.20–1.37	1,721	1.31**	1.25–1.37
MN of larynx	17	1.12	0.65–1.79	33	1.41	0.97–1.99	57	1.28	0.97–1.66
MN of trachea, bronchus and lung	564	1.32**	1.21–1.43	821	1.25**	1.17–1.34	1,619	1.29**	1.23–1.35
MN of other parts of the respiratory system	10	2.16*	1.03–3.97	27	3.82**	2.52–5.55	45	3.32**	2.42–4.44
MN of breast	1	0.63	0.02–3.50	4	1.69	0.46–4.32	5	1.10	0.35–2.56
MN of male genital organs	147	1.12	0.95–1.32	170	0.91	0.78–1.05	364	1.01	0.91–1.11
MN of urinary organs	68	0.98	0.76–1.24	98	0.95	0.77–1.16	195	0.98	0.85–1.13
MN of other and unspecified sites (major)	161	1.10	0.94–1.28	273	1.23**	1.09–1.39	515	1.19**	1.09–1.30
MN of skin melanoma	21	1.20	0.75–1.84	18	0.69	0.41–1.08	49	0.93	0.69–1.24
MN of brain and other parts of the nervous system	31	1.08	0.73–1.53	40	0.90	0.64–1.22	83	0.96	0.76–1.18
MN of other and unspecified sites (minor)	96	1.17	0.95–1.43	186	1.51**	1.30–1.74	334	1.40**	1.25–1.56
Neoplasms of lymphatic and hematopoietic tissue	133	1.14	0.95–1.35	172	0.99	0.84–1.14	346	1.02	0.91–1.13
Non-Hodgkin's lymphoma	54	1.24	0.93–1.61	54	0.82	0.62–1.07	121	0.94	0.78–1.13
Hodgkin's disease	5	0.83	0.27–1.93	8	0.89	0.38–1.75	16	0.91	0.52–1.47
Leukemia and aleukemia	47	0.99	0.73–1.31	79	1.13	0.89–1.40	144	1.05	0.89–1.24
Myeloma	27	1.36	0.90–1.98	31	1.04	0.71–1.48	65	1.13	0.87–1.44
Benign and unspecified neoplasms	13	0.87	0.46–1.49	23	1.02	0.65–1.53	39	0.90	0.64–1.23
Tuberculosis	8	1.15	0.50–2.27	4	0.38*	0.10–0.98	13	0.67	0.36–1.15
Diabetes mellitus	79	0.84	0.67–1.05	91	0.66**	0.54–0.82	199	0.75**	0.65–0.86
Diseases of the blood and blood forming organs	13	0.74	0.39–1.26	20	0.77	0.47–1.19	41	0.82	0.59–1.11
Mental, psychoneurotic and personality disorders	32	0.70*	0.48–0.99	53	0.77	0.58–1.01	98	0.73**	0.59–0.89
Diseases of the nervous system and sense organs	57	0.77	0.59–1.00	106	0.96	0.79–1.17	185	0.87	0.75–1.00
Parkinson's disease	16	0.76	0.43–1.23	26	0.84	0.55–1.23	46	0.78	0.57–1.04
Diseases of the heart	2,057	0.98	0.93–1.02	2,945	0.95**	0.92–0.99	5,680	0.96**	0.93–0.98
Ischemic heart disease	1,757	0.97	0.92–1.01	2,512	0.94**	0.90–0.98	4,849	0.95**	0.92–0.98
Chronic disease of the endocardium	28	1.52*	1.01–2.19	41	1.49*	1.07–2.03	76	1.42**	1.12–1.78
Cardiomyopathy	56	1.48**	1.12–1.92	71	1.24	0.97–1.57	145	1.28**	1.08–1.50
Other diseases of the circulatory system	531	0.96	0.88–1.05	721	0.94	0.87–1.01	1,420	0.95	0.90–1.00
Diseases of the respiratory system	443	0.95	0.86–1.04	711	1.05	0.97–1.13	1,307	1.00	0.95–1.05
Chronic and unspecified bronchitis	18	1.23	0.73–1.95	24	1.12	0.72–1.67	47	1.17	0.86–1.56
Emphysema	75	1.02	0.80–1.28	124	1.14	0.95–1.36	210	1.03	0.89–1.18
Asthma	4	0.74	0.20–1.88	6	0.73	0.27–1.58	12	0.75	0.38–1.30
Asbestosis	4	3.91*	1.06–9.99	27	17.55**	11.56–25.53	33	11.07**	7.62–15.55
Other respiratory diseases	198	0.99	0.85–1.13	328	1.10	0.98–1.22	614	1.07	0.98–1.15

(*Continued*)

TABLE IV. (*Continued*)

	Plumbers			Pipe/steam-fitters			All trades combined		
Underlying cause of death	**OBS**	**PMR**	**95% CI**	**OBS**	**PMR**	**95% CI**	**OBS**	**PMR**	**95%**
Diseases of the digestive system	180	0.86*	0.74–0.99	309	0.98	0.87–1.09	565	0.93	0.85–1.01
Cirrhosis of the liver	91	0.95	0.76–1.16	154	1.02	0.87–1.20	289	1.00	0.88–1.12
Diseases of the genitourinary system	66	0.84	0.65–1.07	81	0.74**	0.58–0.91	163	0.76**	0.65–0.89
Diseases of the skin and subcutaneous tissue	6	1.33	0.48–2.89	6	0.92	0.34–2.00	14	1.11	0.61–1.86
Diseases of the musculoskeletal system	13	1.28	0.68–2.20	14	0.92	0.51–1.55	30	1.03	0.69–1.47
Symptoms and ill-defined conditions	51	0.98	0.73–1.29	118	1.50**	1.24–1.79	194	1.27**	1.10–1.46
Accidents	204	0.96	0.83–1.10	346	1.10	0.99–1.22	694	1.08	1.00–1.16
Transportation accidents	94	0.90	0.73–1.10	184	1.20*	1.03–1.38	362	1.13*	1.01–1.25
Accidental poisoning	8	0.69	0.30–1.36	18	0.95	0.57–1.51	41	1.04	0.75–1.41
Accidental falls	30	0.86	0.58–1.22	58	1.18	0.90–1.53	100	1.04	0.84–1.26
Other accidents	65	1.19	0.92–1.52	79	0.97	0.77–1.21	174	1.06	0.91–1.24
Violence	94	0.84	0.68–1.03	182	1.07	0.92–1.24	349	1.00	0.90–1.11
HIV-related	7	0.65	0.26–1.34	4	0.19**	0.05–0.49	17	0.38**	0.22–0.61
Other causes	74	0.86	0.67–1.08	116	0.91	0.75–1.09	218	0.86*	0.75–0.98

OBS, observed deaths; PMR, proportionate mortality ratio; CI, confidence interval; MN, malignant neoplasm.
*Two-sided *P*-value <0.05.
**Two-sided *P*-value <0.01.

discussed earlier, these categories routinely included deaths resulting from mesothelioma or related diseases. A PMR cannot be calculated for deaths from mesothelioma since ICD codes for mesothelioma did not exist until the 10th revision (beginning in 1999). For deaths occurring prior to 1999, cause of death due to mesothelioma can only be determined by a manual review of death certificates. The numbers of mesothelioma deaths by year and by trade are reported in Table VII. There were 13 deaths from mesothelioma in 1979, accounting for 0.3% of all union deaths occurring in that year. That figure increased to 35 deaths (0.9% of total) in 1987 and 57 deaths (1.4% of total) in 1995. While the number of mesothelioma deaths increased considerably among plumbers between 1979 (2 deaths) and 1995 (12 deaths), the overall number of deaths among pipe/steam-fitters was much higher (9 in 1979, 36 in 1995).

Other Notable Cause-of-Death Results

The ‘‘diseases of the heart’’ cause-of-death category reflected slightly lower than expected proportionate mortality (PMR = 0.96, CI: 0.93–0.98). However, two sub-categories of heart disease—chronic disease of the endocardium and cardiomyopathy—were elevated in the combined analysis. Chronic disease of the endocardium was elevated across both the plumbers (PMR = 1.52, CI: 1.01–2.19) and pipe/steam-fitters (PMR = 1.49, CI: 1.07–2.03) while cardiomyopathy was primarily elevated among plumbers (PMR = 1.48, CI: 1.12–1.92). Chronic disease of the endocardium and cardiomyopathy followed a similar temporal pattern, with a spike in 1979 and lower, though elevated, results in other years. The PMR for cardiomyopathy was significantly elevated among cohort members with 30 years or more of estimated employment.

Proportionate mortality from accidents was elevated in the combined cohort analysis (PMR = 1.08, CI: 1.00–1.16) and pipe/steam-fitter trade (PMR = 1.10, CI: 0.99–1.22) but not in the analysis of plumbers (PMR = 0.96, CI: 0.83–1.10). Proportionate mortality from transportation accidents was elevated overall in the pipe/steam-fitter trade (PMR = 1.20, CI: 1.03–1.38) with the highest PMRs in 1971 (PMR = 1.33) and 1979 (PMR = 1.42). However, in 1995, proportionate mortality for transportation accidents in the pipe/steam-fitter trade was significantly reduced (PMR = 0.59). Deaths from work-related transportation accidents could not be differentiated from all other transportation accident deaths in this analysis. The results displayed in Table VIII divided transportation accident proportionate mortality between those who were likely to be still working (<60 years of age) and those who had likely retired (≥ 60 years of age). Proportionate mortality was elevated for pipe/steam-fitters who died before age 60 (PMR = 1.23, CI: 1.03–1.46) but not for pipe/steam-fitters who died at age 60 years or older (PMR = 1.13, CI: 0.85–1.48). No

TABLE V. Proportionate Mortality Ratios (Reference U.S. White Male Deaths) for UA Selected Causes of Death Among Plumbers, Pipe/Steam-Fitters and All Trades Combined by Year of Death and Overall

	Year of death				
Trade: underlying cause of death	**1971**	**1979**	**1987**	**1995**	**Total**
Plumbers					
All cancers	1.24**	1.28**	1.14*	1.10*	1.18**
MN of larynx	1.30	1.57	1.06	0.54	1.12
MN of trachea, bronchus and lung	1.23*	1.46**	1.28**	1.30**	1.32**
Neoplasms of lymphatic and hematopoietic tissue	1.44*	1.07	1.18	0.95	1.14
Diseases of the nervous system and sense organs	0.78	0.68	0.93	0.70	0.77
Parkinson's disease	0	0.40	1.33	0.74	0.76
Chronic disease of the endocardium	1.38	4.64**	1.49	1.05	1.52*
Cardiomyopathy	0.57	2.92**	1.24	1.45	1.48**
Diseases of the respiratory system	0.87	1.01	0.89	1.01	0.95
Asbestosis	0	0	6.70	3.44	3.91*
Accidents	0.93	1.07	0.96	0.85	0.96
Transportation accidents	0.83	1.17	0.51*	1.13	0.90
Pipe/steam fitters					
All cancers	1.01	1.15**	1.16**	1.14**	1.12**
MN of larynx	0.66	1.10	2.36**	1.59	1.41
MN of trachea, bronchus and lung	1.11	1.38**	1.26**	1.25**	1.25**
Neoplasms of lymphatic and hematopoietic tissue	1.08	0.88	1.08	0.91	0.99
Diseases of the nervous system and sense organs	0.70	1.03	0.90	1.06	0.96
Parkinson's disease	0	1.05	0.99	0.87	0.84
Chronic disease of the endocardium	3.97*	4.70**	0.97	1.16	1.49*
Cardiomyopathy	1.09	1.30	1.11	1.36	1.24
Diseases of the respiratory system	1.02	1.03	0.98	1.13	1.05
Asbestosis	0	13.49*	16.65**	20.77**	17.55**
Accidents	1.24*	1.23*	1.06	0.72*	1.10
Transportation accidents	1.33*	1.42**	1.14	0.59*	1.20*
All trades combined					
All cancers	1.10*	1.20**	1.15**	1.13**	1.15**
MN of larynx	0.87	1.35	1.73*	1.12	1.28
MN of trachea, bronchus and lung	1.16*	1.42**	1.27**	1.27**	1.29**
Neoplasms of lymphatic and hematopoietic tissue	1.17	0.94	1.10	0.91	1.02
Diseases of the nervous system and sense organs	0.81	0.95	0.84	0.87	0.87
Parkinson's disease	0	0.83	0.99	0.80	0.78
Chronic disease of the endocardium	2.75	4.26**	1.06	1.14	1.42**
Cardiomyopathy	0.84	1.77*	1.11	1.33*	1.28**
Diseases of the respiratory system	0.94	0.98	0.95	1.08	1.00
Asbestosis	0	7.37	11.05**	12.74**	11.07**
Accidents	1.11	1.22**	1.02	0.88	1.08
Transportation accidents	1.10	1.41**	0.92	0.92	1.13*

MN, malignant neoplasm.
*Two-sided P-value <0.05.
**Two-sided P-value <0.01.

elevations were found when results were stratified by duration of employment.

Borderline elevations were detected for cancers of the esophagus (PMR = 1.22) and stomach (PMR = 1.21) when the entire cohort was examined, but not when plumbers and pipe/steamfitters were analyzed separately.

Proportionate mortality from diabetes (PMR = 0.75, CI: 0.65–0.86), mental disorders (PMR = 0.73, CI: 0.59–0.89),

TABLE VI. Proportionate Mortality Ratios (Reference U.S. White Male Deaths) for UA Selected Causes of Death (1979, 1987, and 1995) by Estimated Duration of Employment (Limited to 8,424 UA Members With an "Initiate" Status Shown in the Database and 20 Years or More of Potential Latency)

	Estimated duration of employment[a]							
	<20 years		20–29 years		30+ years		Total	
Underlying cause of death	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All cancers	411	1.07	1,083	1.16**	1,004	1.19**	2,498	1.16**
MN of larynx	3	0.77	10	0.93	20	1.98**	33	1.33
MN of trachea, bronchus and lung	158	1.33**	434	1.34**	407	1.31**	999	1.33**
Neoplasms of lymphatic and hematopoietic tissue	29	0.83	86	1.01	68	0.90	183	0.93
Diseases of the nervous system and sense organs	35	1.23	62	1.03	36	0.79	133	0.99
Parkinson's disease	12	1.18	17	0.94	9	0.73	38	0.94
Chronic disease of the endocardium	11	1.28	23	1.37	11	0.86	45	1.18
Cardiomyopathy	14	1.17	37	1.09	46	1.42*	97	1.24*
Diseases of the respiratory system	192	1.01	369	1.07	267	0.99	828	1.03
Asbestosis	1	2.50	14	15.44**	10	11.66**	25	11.55**
Accidents	24	0.72	100	0.93	64	0.87	188	0.88
Transportation accidents	8	0.80	43	0.94	25	0.82	76	0.88

OBS, observed deaths; PMR, proportionate mortality ratio; MN, malignant neoplasm.
*Two-sided P-value <0.05.
**Two-sided P-value <0.01.
[a]Duration of employment estimated from initiate date to earlier of the date of death and age 60 years.

TABLE VII. Distribution of UA Mesothelioma Deaths by Trade Group and Year of Death

	Year of death				
Trade	1971[a]	1979[b]	1987[b]	1995[b]	Total
Plumbers	N/A	2	8	12	22
Pipe/steam-fitters	N/A	9	22	36	67
Metal trades	N/A	0	0	3	3
Sprinkler fitters	N/A	0	2	0	2
Lead burner	N/A	0	0	0	0
Other and unknown	N/A	0	0	0	0
Mixed	N/A	2	3	6	11
Total	7 (0.2%)[c]	13 (0.3%)	35 (0.9%)	57 (1.4%)	112 (0.7%)

[a]Mesothelioma deaths in 1971 from Table II in Kaminski et al. [1980]. Note that Kaminski et al. did not report mesothelioma deaths by trade group.
[b]Mesothelioma deaths in 1979, 1987, and 1995 were identified by a manual review of the death certificates. Of 105 identified mesothelioma deaths in these years, 31 were mapped to "MN of other parts of the respiratory system" (1 with ICD-9 code 163.0 = MN of pleura, parietal; 30 with ICD-9 code 163.9 = MN of pleura, unspecified) and 74 were mapped to "MN of other and unspecified sites (minor)" (3 with ICD-9 code 195.1 = MN of other and ill-defined sites, thorax; 71 with ICD-9 code 199.1 = MN without specification of site, other).
[c]Number in parentheses is percent of deaths due to mesothelioma among all deaths in the given year.

diseases of the genitourinary system (PMR = 0.76, CI:0.65–0.89) and HIV-related causes (PMR = 0.38, CI:0.22–0.61) was lower than expected.

DISCUSSION

This study expands the NIOSH proportionate mortality analysis of the UA that utilized 3,369 death certificates from the year 1971 to include analysis of deaths from 1979, 1987, and 1995. All cancers, lymphatic cancer, diseases of the respiratory system and diseases of the heart demonstrate relatively flat proportionate mortality. Proportionate mortality from lung cancer, asbestosis and mesothelioma has

TABLE VIII. Proportionate Mortality (Reference U.S. White Male Deaths) for UA Accident and Transportation Accident Deaths (1971, 1979, 1987, and 1995) by Age at Death Among Pipe/Steam-Fitters

	Accidents—all			Accidents—transportation		
Age at death	OBS	PMR	95% CI	OBS	PMR	95% CI
<60 years	211	1.16*	1.01–1.32	131	1.23*	1.03–1.46
≥60 years	135	1.02	0.86–1.21	53	1.13	0.85–1.48

OBS, observed deaths; PMR, proportionate mortality ratio; CI, confidence interval.
*Two-sided P-value <0.05.

increased, which is consistent with the increased use of asbestos during this cohort's working years and the work-related asbestos exposures experienced by many members of the UA.

These findings are largely consistent with the results of a mortality study conducted by Finkelstein and Verma [2004] involving only the Canadian locals of the UA (whereas this paper examines only the U.S. locals). The significant results of the two studies are similar: all cancers, lung cancer, asbestosis, and mesothelioma were elevated throughout both cohorts, with equivocal elevations detected for lymphatic cancer. A PMR study evaluating patterns of proportionate mortality among 7,121 white male deceased members and retirees of California locals of the UA who died in the years 1960–1979 also confirmed the primary findings of elevated proportionate mortality from lung cancer, asbestosis and mesothelioma [Cantor et al., 1986].

Elevated proportionate mortality from lung cancer may be confounded by the smoking patterns of plumbers and pipefitters. While the specific smoking patterns of the UA members used in this analysis are not known, several studies have provided survey-based estimates of the overall smoking prevalence among occupations, including plumbers and pipefitters. The National Health Interview Survey, a nationally representative survey that has tracked smoking rates in the United States for over 30 years, found that plumbers and pipefitters had a smoking prevalence that was 10% higher than for the general male population [Brackbill et al., 1988; Nelson et al., 1994]. While it is likely that this higher smoking prevalence would be a contributing factor to increased lung cancer proportionate mortality, the significance of that contribution is difficult to estimate. Several studies have attempted to quantify the impact of smoking on lung cancer risk in this population. A survey of 293,958 U.S. veterans in 1953 and 1957 captured information about occupation and smoking habits; elevated mortality (1954–1970) from cancer of the lung (SMR = 1.84) was reported for those veterans who went into the plumbing and pipefitting trades [Blair et al., 1985]. Little difference in lung cancer mortality was detected between the smoking and the non-smoking portions of the cohort. Levin et al. [1990] examined smoking patterns [non-smoker, former, current ($\leq$1 pack per day, >1 pack per day)] and occupation among controls for the National Bladder Cancer study and used Axelson's method to estimate that smoking habit confounding would only explain a 10% increase in the risk ratio for lung cancer among plumbers and pipefitters, relative to all occupations. Finally, Finkelstein and Verma [2004] used estimates of smoking prevalence (ever, never) from the U.S. National Health Interview Survey (1987–1990) to estimate that smoking habit confounding could account for a relative risk of 24% for plumbers, pipefitters and steamfitters relative to the general population. Based on these studies, it is unlikely that smoking prevalence alone would have accounted for the elevated proportionate lung cancer mortality reported in the current study of deceased UA members.

Mesothelioma and asbestosis are the causes of death most closely related to asbestos exposure. The number of mesothelioma deaths almost tripled between 1979 and 1987 and increased another 60% between 1987 and 1995. Proportionate mortality from asbestosis was significantly elevated in this cohort. The PMR for asbestosis also increased for each year of this analysis, with a PMR of 12.74 by 1995.

In work performed by UA members, the principal activities leading to asbestos exposure involved the tear-out or disturbance of asbestos-containing insulation, including spray-on insulation, and the handling and cutting of cement pipe and sheeting materials. In construction, the highest exposures in the U.S. occurred from the 1930s through the 1960s [Nicholson et al., 1982]. Changes made in reference section. The U.S. Environmental Protection Agency banned spray-on insulation in 1973 for most applications and the U.S. Occupational Safety and Health Administration imposed exposure regulations for most other work beginning in 1972, and continued to reduce permissible exposure levels in 1976, 1986, and 1994. Although virtually no longer used in manufacturing of products in the United States, asbestos is still pervasive in many occupational settings and materials containing asbestos continue to be available in imported products.

Based on the usage patterns of asbestos [Virta, 2006] and an assumed 35–50 years latency for the onset of mesothelioma [NCI, 2002], it has been projected that mesothelioma incidence would continue to increase until at least the year 2020 [Niklinski et al., 2004] and then steadily decrease to background levels around the year 2050 [Price, 1997]. Since 75% of all mesothelioma cases die within 2 years of diagnosis [Ries et al., 2006], it follows that mesothelioma mortality would begin to decline around the year 2022. Reports of death from the National Occupational Respiratory Mortality System (NORMS) support these projections. The number of mesothelioma deaths have increased from 2,343 in 1999 to 2,429 in 2002 to 2,502 in 2004 [NIOSH, 2006]. Obviously, additional mortality data after 2004 will be needed to evaluate true mesothelioma mortality trends.

The number of asbestosis deaths and the age-adjusted death rate have steadily increased since reporting began in 1968. Although the onset of asbestosis may occur within 10–20 years after initial exposure to asbestos [ATSDR, 2008], asbestosis mortality peaks at 40–45 years latency. Considering the 40–45 years peak latency, it has been estimated that asbestosis mortality will continue to increase at least until the year 2014 [CDC, 2004]. This prediction appears to be accurate. The number of asbestosis deaths, which averaged approximately 350 deaths annually in the mid-1990s, increased to 458 in 1998, 561 in 2000, and 585 in 2003. The asbestosis age-adjusted death rate has also increased from 1.75/1,000,000 deaths in 1995 to 2.17 in

1998, and 2.57 in 2000 and 2003. There are indications that the age-adjusted rate may have reached a plateau during the period 2000–2004 (last years reported), but there is no indication of a downward trend [NIOSH, 2006].

Elevated heart disease mortality due to cardiomyopathy and chronic diseases of the endocardium is not commonly found in studies of occupational cohorts and has not been previously reported in other studies of plumbers/pipefitters. While cohorts exposed to cardiotoxic substances such as carbon monoxide, carbon disulfide and methylene chloride have exhibited increased mortality from myocardial infarction and atherosclerotic ischemic heart diseases, few studies have specifically connected cardiomyopathy and endocardial diseases to occupational exposures. Several studies have implicated high solvent and heavy metal exposure to increased mortality from cardiomyopathy and endocardial diseases, but the evidence is limited and weak [Rosenman, 1984; Benowitz, 1992]. For this cohort, the proportionate mortality for these causes was highest for both plumbers and pipe/steam-fitters in the earlier years of the analysis. UA workers who died from these diseases in 1971 and 1979 may have been exposed to agents in the workplace during their working years (1940s–1950s) that were no longer in use in the 1960s and 1970s. Asbestos exposure could be a contributing factor to these specific cardiovascular disease elevations. The connection between various cardiovascular diseases and asbestos exposure has been a consistent observation for many years, presumably due to the extreme stress placed on the cardio-pulmonary system of affected workers. For example, in a study of asbestos textile workers, mortality from heart disease was significantly elevated (SMR = 1.38) [Hein et al., 2007]. Recent medical studies have noted cardiovascular morbidity among patients with prior asbestos-related work or with concurrent mesothelioma [Roggeri et al., 2003; Senkottaiyan et al., 2006].

Mortality from injuries/accidents has generally not been elevated in the few studies that have reported on this outcome among plumbers/pipefitters. In this study, an examination of cause-specific accident proportionate mortality by trade identified an elevation in transportation accidents among pipe/steam-fitters, primarily in the earlier years of the analysis. These results were confirmed in Cantor et al. [1986], the only other study that reported transportation accident proportionate mortality by trade. The Finkelstein and Verma [2004] study did not break out transportation accidents and a study by Wang et al. [1999] did not differentiate transportation accidents by trade. The transportation accident proportionate mortality analysis reported in Table VII separates those who were likely still to be working ($<$60 years of age) from those who likely had retired ($\geq$60 years of age). Results are elevated for those who died in transportation accidents prior to age 60, indicating a possible occupational connection. However, the elevated results are relegated to the 1971 and 1979 deaths. The 1995 results actually show decreased proportionate mortality due to transportation accidents. It is not possible to ascertain the work-related nature of accidents based on cause-of-death codes alone. Excess mortality from transportation accidents has been found in other construction trades (carpenters, laborers) and should continue to be monitored for the plumber/pipe-fitter trades [Stern et al., 1995; Robinson et al., 1996].

The multiple-cause-of-death analysis is useful in identifying diseases such as diabetes, musculoskeletal disorders, and renal disease that are of long duration, not necessarily fatal, but are still serious occupational health problems. Results of the multiple-cause-of-death analysis are not shown since no multiple cause of death category exhibited a significant difference from the underlying cause-of-death results.

Strengths of Study

This is the largest proportionate mortality study of the plumbing and pipe/steam-fitting trades that has been conducted in the United States. An analysis of over 15,000 deaths allowed an examination of even relatively rare causes of death. The sampling of deaths from years encompassing a 25-year span provided an examination of the proportionate mortality of a workforce that had encountered significantly differing occupational exposures and work practices over the course of their careers. This sampling did highlight differences across the years, especially the continuing impact of asbestos in the workplace in spite of increased regulatory restrictions that began in the late 1970s.

PMR studies based on union records provide much more accurate occupational information than do studies based on death certificates or other sources of occupational surveillance data. In addition, PMR studies based on datasets that are maintained to pay death benefits to the survivors of deceased workers provide PMR estimates that are more similar to standardized mortality ratio results [Beaumont and Okun, 1981].

The NIOSH Mortality Data by Occupation, Industry, and Disease data set, which contains the results of a PMR analysis of data from the National Occupational Mortality Surveillance (NOMS) system, also supports the primary findings. The NOMS system is based on death certificate data collected from 24 states, for one or more years during the period 1984–1988, with coded occupation and industry information. For plumbers, pipefitters and steamfitters, the NOMS PMR data found elevated proportionate mortality from all cancer, cancer of the respiratory organs, cancer of the trachea/bronchus/lung, cancer of the pleura, pneumoconiosis, and asbestosis [NIOSH, 2004].

Study Limitations

The limitations of the PMR analysis are well documented [Decoufle et al., 1980; Robins and Blevins, 1987;

Stewart and Hunting, 1988]. The PMR does not provide a true estimate of risk. It is an analysis tool commonly used when the total population at risk is not known and only death information on the cohort under study is available. Since the UA obtains death information on its membership for pension purposes, a PMR study is a relatively quick and effective way of detecting unusual or elevated causes of death among their memberships.

Work histories could not be assembled since start and end dates of employment and periods of unemployment were not recorded in the UA master file. The master file did not contain adequate local affiliation data to allow for a more detailed analysis of locals that may have experienced unique exposures, such as radiation exposure from work at a nuclear power plant. Likewise, individual-level information about work processes and job assignments were not recorded.

This study only included deaths reported to the UA for members eligible for death benefits. This study restriction thus excludes: (1) members whose survivors did not file a claim for the death benefit and (2) members who had worked as a union plumber or pipefitter but allowed their membership to lapse prior to retirement or death. It has been postulated that the latter limitation could result in biased study results if such workers left work early due to occupational exposures that were irritating or caused work-prohibiting illness [Robins, 1987]. While officers of the UA believed that ''the vast majority'' of members who retired maintained their membership until death, they were unable to estimate the percentage of members who let their membership lapse prior to retirement (Personal communication, William C. Rhoten, UA Director of Safety and Health, March 1, 2004). Since the entire population at risk cannot be fully ascertained, the results of this analysis may not be representative of the overall mortality experience of all workers who had substantial employment in plumbing and pipefitting occupations.

Finally, no individual smoking histories were available and the impact of smoking habits on certain causes of death could not be accurately determined.

CONCLUSION

Although PMR studies are clearly exploratory in nature and do not provide a true estimate of risk, they are useful tools in determining areas for more detailed study or for improved training or intervention activities [Wong and Decoufle, 1982; Wong et al., 1985]. Since the national construction trade unions obtain death information on their memberships for pension purposes, PMR studies have been found to be a relatively quick and effective way of detecting unusual or elevated causes of death among their memberships.

The Occupational Safety and Health Administration (OSHA) has issued explicit regulations designed to control worker exposures to asbestos [OSHA, 2006]. These regulations cover employer and employee responsibilities in the areas of training, exposure monitoring, personal protective equipment, engineering controls, and medical surveillance. It is expected that asbestos-related illness will be significantly reduced for those workers who have been covered by these regulations during their working careers. The results of this study, along with ongoing public health surveillance efforts, make it clear that plumbers and pipe/steam-fitters whose working careers included years not covered by the OSHA standard will continue to experience the adverse health effects of past asbestos exposure for the foreseeable future. Long-term prognosis is still poor for workers stricken by the asbestos-related diseases of mesothelioma, asbestosis and/or lung cancer.

The synergistic effect of smoking and asbestos on lung cancer has been well-established in many studies for many years. It is not possible to reverse the negative health impact of past asbestos exposure but there is evidence that quitting smoking will reduce the risk of lung cancer and asbestosis among asbestos-exposed workers. Smoking elimination campaigns should be targeted to both current and retired workers. There are indications that this message is being heard, at least among younger workers. The most recent analysis of the National Health Interview Survey data for the time period 1987–1994 found that the smoking rates among plumbers and pipefitters exhibited a statistically significant decreasing trend (P-value$<$0.03) between 1987 and 1994 and the overall smoking prevalence had decreased from 40.2% in 1987 to 33.7% in 1994 [Lee et al., 2004; Nelson et al., 2004]. This trend is too recent to have had any impact on the results of the workers who died between 1971 and 1995, but it is a positive sign for the health of current workers.

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