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Proportionate Mortality Among Unionized Construction Ironworkers

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This report presents the results of proportionate mortality ratios (PMR) and proportionate cancer mortality ratios (PCMR) among 13,301 members of the International Union of Bridge, Structural, and Ornamental Ironworkers who had been members for a minimum of 1 year, were actively paying dues into the death beneficiary fund, and had died between 1984–1991. Using the United States proportionate mortality rates as the comparison population, statistically significant elevated risks, using 95% confidence intervals (CI), were observed for several types of injuries: falls (N = 259, PMR = 3.57, CI = 3.15–4.03), transportation injuries (N = 363, PMR = 1.22, CI = 1.10–1.35), and other types of injuries (N = 225, PMR = 1.63, CI = 1.43–1.86). The deaths due to falls were significantly elevated for each 10-year age group under age 60 (PMR >7.00) and for those workers with <20 years in the union (PMR >6.00). Elevated mortality risks were also observed for all malignant neoplasms combined (N = 3,682, PMR = 1.09, CI = 1.06–1.13) as well as for site-specific malignant neoplasms of the lung (N = 1,523, PMR = 1.28, CI = 1.21–1.35), pleural mesothelioma (N = 7, PMR = 1.67, CI = 0.67–3.44) and "other and unspecified sites" (N = 307, PMR = 1.29, CI = 1.15–1.44). The category "pneumoconiosis and other respiratory diseases" was also significantly elevated (N = 690, PMR = 1.11, CI = 1.03–1.20); in this category, deaths due to asbestosis had the greatest elevated risk (N = 10, PMR = 3.56, CI = 1.70–6.54). No elevation in risk was found for kidney cancer or for chronic nephritis which were of interest because of Ironworkers' potential exposure to lead. The present study underscores the importance of fall protection and other injury prevention efforts in the construction industry, as well as the need to control airborne exposures to asbestos, welding fumes and other respirable disease hazards. Am. J. Ind. Med. 31:176–187, 1997. *© 1997 Wiley-Liss, Inc.*

KEY WORDS: ironworker; construction; proportionate mortality; injuries; lung cancer

INTRODUCTION

The International Union of Bridge, Structural, and Ornamental Ironworkers (henceforth termed as Ironworkers) was founded in 1896 and known as the International Association of Bridge and Ironworkers of America. From its relatively small beginning of less than 2,000 members, the Ironworkers has grown to approximately 123,000 members as of 1994 (96,200 active members and 26,800 retirees). The members are located within 261 separate Locals throughout the United States and Canada. Member activities include, but are not limited to, fabrication, production, erection, and construction involving iron, steel, ornamental lead, bronze, brass, copper, aluminum, and ferrous and nonferrous metals used in buildings. The Ironworkers Union mainly consists of bridge, structural, ornamental, and reinforced concrete iron workers, welders, rodmen, machinery movers, stone derrickmen, shopmen, and navy yard riggers, among other skilled members. Ironworkers are divided into 24 specialty skills (Table I), but more than 98% of their work is performed in one of nine skill areas (Table II). Ironworker locals are also classified into 1 of 11 specialty types (Table III).

Because Ironworkers perform many varied duties, they have the potential for exposure to numerous physical and

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TABLE I. Speciality Skills of Ironworkers[a]

Skill	No. in study population	Study population (%)
Ironworker	6,346	47.7
Shopman	2,801	21.1
Rodman	1,617	12.2
Welder	752	5.7
Rigger, Mach. Mover & Erector	505	3.8
Structural Ironworker	461	3.5
Finisher	441	3.3
Sheeter	139	1.0
Fence Erector	92	0.7
Journeyman Latherer Rodman	59	0.4
Stone Derrickman	24	0.2
Speciality Building Erector	9	0.1
Town Erector	4	0.0
Ironworker Skill—D	4	0.0
Trainee	3	0.0
Ironworker Maint. Mechanic	1	0.0
Surveyor	0	0.0
Precast Erector	0	0.0
Atomic Maint. Worker	0	0.0
Indus. Door Mech. Erector	0	0.0
Navy Yard Rigger	0	0.0
Heavy and Highway Ironworker	0	0.0
Ironworker Skill—E	0	0.0
Ironworker Skill—F	0	0.0
Total	13,258	99.7

[a]Data obtained from International Association of Bridge, Structural, and Ornamental Ironworkers [1993]. Skills were not listed for 43 members of the study.

TABLE II. Description of Top Nine Skills of Ironworkers[a]

Skill	Description
Shopman	Works inside the Fabrication Shop. Takes raw steel and fabricates it to the desired size and shape.
Ironworker	Performs any combination of duties to raise, place, and unite girders, columns, and other structural steel members to form completed structures or structure frameworks, working as a member of a crew.
Structural Ironworker	Errects bridges, buildings and other large structures. Puts up the framework.
Rodman	Places steel reinforcements in concrete forms to strengthen the concrete.
Finisher	(Also known as Ornamental Ironworker). Installs ornamental iron and steel, architectural metals, handrails, revolving doors, and other decorative work. Also installs windows, bathroom fixtures, glass cabinets, and mirrors.
Rigger	Loads, unloads, transports and installs heavy equipment such as large air conditioning units, steam drums for power plants, and nuclear reactors. Riggers use fiber line, wire rope, chains and hooks, slings, hoisting equipment, anchorages, skids, and rollers to perform the above work.
Stone Derrickman	Places prefabricated concrete or stone panels on multi-story buildings.
Sheeter	Installs sheet steel on the outside of building structures.
Welder	Performs any and all kinds of welding operations on steel or iron as needed.

[a]Phone contact with Mr. James Cole, General Treasurer, International Association of Bridge, Structural, and Ornamental Ironworkers.

chemical agents. Often these exposures can be episodic in nature. In addition, because Ironworkers work in close proximity to other construction trade craftspersons and laborers, whose tasks and work practices also vary widely, they may be exposed to other hazardous materials as well. Potential toxic exposures specific to Ironworkers at the job site, as described by the National Occupational Exposure Survey (NOES) conducted by the National Institute for Occupational Safety and Health (NIOSH) [NIOSH 1988, 1990a,b], include, among many others, inorganic lead, welding fumes, asbestos, solvents, and carbon monoxide. Based on these exposures, causes of death hypothesized to be elevated in the cohort included lung cancer as well as respiratory and renal diseases. Excess deaths from occupational injury were also of concern due to the types of Ironworkers' activities and the heights at which they are performed.

The purpose of our study was to identify causes of death in excess among Ironworkers as a starting point for intervention and prevention activities. Although some studies have examined occupational risks of specific local unions, no one to date has examined the Ironworkers union in its entirety and to such a large scale.

MATERIALS AND METHODS

Study Population

Our study population consisted of all deceased Ironworkers who (1) had been active dues-paying members of the International Association of Bridge, Structural, and Ornamental Ironworkers (Ironworkers) for a least one continuous year; (2) were actively paying into the death beneficiary fund at the time of their death whether they were currently employed, unemployed, or retired; and (3) had died between January 1, 1984 and December 31, 1991.

The Ironworkers death beneficiary fund has been computerized since May 1984 with approximately 2,000 deaths per year, and this file was provided to the National Institute for Occupational Safety and Health (NIOSH) by

TABLE III. Ironworkers Locals Classified as to Type[a]

Code classification	Description	No. in population	Population (%)
AO	Architectural and Ornamental Ironworker	144	1.1
M	Mixed	7,960	59.8
MR	Machinery Movers, Erectors, Riggers	199	1.5
O	Ornamental Ironworkers	197	1.5
R	Rodman	474	3.5
S	Structural Ironworker	596	4.5
SD	Stone Derrickmen	23	0.2
SH	Shopmen	2,689	20.2
SMR	Structural, Machinery Movers, and Riggers	526	4.0
SO	Structural and Ornamental	465	3.5
YR	Navy Yard Riggers	28	0.2
Total:		13,301	100.0

[a]Last local of ironworker used.

the International headquarters of the Ironworkers. Because the computerized death beneficiary fund was started in 1984, the study included deaths occurring between 1984–1991; 1991 was the most recent full year for which death certificates had been compiled by the Ironworkers prior to our study.

The study population and their demographics were identified from the computerized death beneficiary and membership files maintained at the International headquarters of the Ironworkers. The following information, among other variables, was retrieved from these files for each member in the study: name, Social Security number, date of birth, race, gender, the majority of time in a skill category (Tables I,II), years of active paying status, year of entry into the union, local unions worked in and periods of time worked in each local, date of death, and underlying cause of death (which was printed out). Each local was designated as to the major type of construction activity that it participated in (Table III).

The study group included all eligible members for whom a death benefit claim had been filed as well as those few members known to be deceased by the Ironworkers through their local and placed on the death beneficiary file, but for whom a death benefit claim had not been filed by the beneficiary (N = 472). The few members in the Ironworkers computerized death beneficiary files who died either before 1984 or after 1991 were excluded from our analysis (N = 293). Death certificates were obtained for each eligible member. Underlying and contributory causes of death from the death certificates were coded by an experienced and qualified nosologist according to the Ninth Revision of the International Classification of Diseases (ICD-9)[WHO, 1977].

Statistical Analyses

We conducted three types of proportionate mortality ratio (PMR) analyses using the National Institute for Occupational Safety and Health (NIOSH) Life Table Analysis System (LTAS): one that evaluated the overall proportionate mortality, a second that evaluated the proportionate cancer mortality [Steenland et. al., 1990], and a third that compared the number of death certificates with any mention of a specified cause of death based on that expected using multiple cause-of-death referent rates [Steenland et al., 1992]. The PMR methodology was used in lieu of the Standardized Mortality Ratio (SMR), which gives a true estimate of the disease risk, because we did not have the entire population at risk. The number of deaths in the study population for 92 causes of death, was compared with the number of deaths expected. Expected rates were based on race, gender, and cause-specific proportionate mortality experience of the U.S. population by the 5-year calendar-time periods 1980–1984, 1985–1989, and 1990–1994, and by 5-year age groups starting at age group 15–19. The PMRs were then calculated by dividing the observed number of deaths by the number expected and multiplying the results by 100. Statistical significance of the results was determined using the Poisson distribution and 95% confidence intervals (CI). If the observed number of deaths was greater than 6, the Byar approximation to the exact test was used; if the observed number of deaths was less than or equal to 6, exact confidence limits were used [Rothman and Boice, 1979]. PMRs were calculated to examine the effect of length of union membership (member paying dues whether employed, unemployed, or retired), year of entry into the union, age at death, type of local, and majority of time in a skill category. Proportionate cancer mortality ratios (PCMRs) were calculated using the same time periods and age groups that were used for the PMR analysis. The PCMR analysis was conducted to correct for possible biases in cancer mortality PMR due to elevations or deficits from other nonmalignant causes, particularly a possible deficit from heart disease deaths due to the ''healthy worker effect.'' A multiple-cause analysis using all the causes of death as coded on the death certificates was conducted to reveal any disease excesses not identified using only underlying causes of death. This analysis includes the usual underlying cause of death as well as contributory causes and other significant conditions which the physician or other medical provider noted on the death certificate.

RESULTS

Characteristics of the Study Population

A total of 14,446 deaths among Ironworkers were initially identified from the Ironworkers' death beneficiary file. From this total we excluded the following: (1) 293 deaths

TABLE IV. Demographic Characteristics of Ironworkers (by Gender and Race) Who Died 1984–1991

Characteristics mean	White male (N = 12,846)	Nonwhite male (N = 434)	Females[a] (N = 21)	Totals (N = 13,301)
Year of birth	1918	1928	1922	1918
Year first entered union	1950	1962	1965	1951
Age first entered union	32	34	43	32
Length of years in union	28	20	15	28
Age stopped paying dues	60	54	58	60
Age of death	69	59	65	69
% of total	96.6%	3.2%	0.2%	100%

[a]Includes 1 nonwhite female.

that occurred either before 1984 or after 1991; (2) 806 deaths that occurred outside the United States; (3) 41 deaths for whom a death certificate could not be obtained; and (4) 5 deaths with erroneous dates of death, resulting in 13,301 deaths for analysis. The general characteristics of the study population by gender and sex are presented in Table IV.

Cause-Specific Mortality Analysis

There were statistically significant elevations in all categories of fatal injuries (except poisonings). The largest elevation was due to falls—a 3.5-fold risk (Table V).

There were also statistically significant elevations in deaths due to all malignant neoplasms, mainly due to significant elevations of cancer of the lung and of other and unspecified sites. Pleural mesothelioma was also highly elevated. The category ''Pneumoconiosis and Other Respiratory Diseases'' was significantly elevated and included a 3.5-fold excess risk of asbestosis.

Diseases of specific interest included renal diseases which may arise from exposure to lead and metal fumes. These included cancer of the kidneys, acute renal failure, chronic nephritis and infections of the kidney. None of these results was found statistically significant.

The proportionate mortality rate for those diseases most associated with smoking (other than lung cancer) i.e., emphysema, bronchitis, cancer of the buccal cavity and pharynx, and heart diseases were all below expectation with the exception of emphysema.

Cancers of the lung and of other and unspecified sites, which were significantly elevated in the PMR analyses, were still significantly elevated in the PCMR analyses (Table VI). The latter category included 35 malignant neoplasms due to mesothelioma. (Note: If mesothelioma was not specified as to pleural or peritoneum, it is coded as unspecified.)

The multiple cause-of-death analysis was found to have very similar ratios between it and the underlying cause-of-death analysis. Those causes of death that were significantly

TABLE V. Observed Number of Deaths, Proportionate Mortality Ratios and 95% Confidence Intervals Among Ironworker Members Who Died 1984–1991

Causes of death (ICDA-9)	Observed no. of deaths	PMR	95% confidence interval
All causes (000–999)	13,301	1.00	0.98–1.02
Tuberculosis (010–018)	13	1.15	0.61–1.97
All malignant neoplasms (140–208)	3,682	1.09[b]	1.06–1.13
Buccal cavity and pharynx (140–149)	65	0.92	0.71–1.17
Cancer of the stomach (151)	117	1.12	0.93–1.35
Cancer of lung (162)	1,523	1.28[b]	1.21–1.35
Pleural mesothelioma (163)	7	1.67	0.67–3.44
Cancer of kidney (189.0–189.2)	77	0.96	0.76–1.21
Cancer of other and unspecified sites (194–199)	307	1.29[b]	1.15–1.44
Benign and unspecified neoplasms (210–240)	44	1.18	0.85–1.58
Diabetes mellitus (250)	158	0.73[b]	0.62–0.85
Diseases of the blood (280–289)	35	0.76	0.53–1.06
Mental, psychoneurotic, and personality disorders (290–319)	101	0.84	0.68–1.02
Alcoholism (303)	31	0.77	0.53–1.10
Diseases of the nervous system (320–389)	161	0.79[b]	0.68–0.93
Diseases of the heart (400–429)	4,575	0.95[b]	0.92–0.98
Ischemic heart disease (410–414)	3,315	0.94[b]	0.90–0.97
Cerebrovascular disease (430–438)	646	0.92[a]	0.85–0.99
Other circulatory system (440–459)	402	0.96	0.89–1.09
Diseases of the respiratory system (460–519)	1,201	1.01	0.95–1.07
Pneumonia (except newborn) (480–486)	306	0.80[b]	0.71–0.89
Bronchitis (490–491)	23	0.88	0.56–1.32
Emphysema (492)	160	1.22[a]	1.04–1.43
Asthma (493)	17	0.92	0.54–1.48
Pneumoconioses and other respiratory diseases (470–478, 494–519)	690	1.11[b]	1.03–1.20
Asbestosis (501)	10	3.56[b]	1.70–6.54
Diseases of the digestive system (520–579)	459	0.94	0.85–1.02
Liver cirrhosis (571)	185	0.83[a]	0.72–0.96
Diseases of the genitourinary system (580–629)	158	0.82[a]	0.70–0.96
Acute renal failure (580–581, 584)	22	1.04	0.65–1.58
Chronic nephritis (582, 583, 585–587)	80	0.84	0.66–1.04
Infection of kidney (590)	8	1.37	0.58–2.69
Diseases of the skin (680–686)	9	0.66	0.30–1.25
Diseases of the musculoskeletal system (710–739)	21	0.86	0.53–1.32
Symptoms and ill-defined conditions (780–799)	152	1.17	0.99–1.38
Injuries (E800–949)	897	1.59[b]	1.49–1.70
Transportation injuries (E800–848)	363	1.22[b]	1.10–1.35
Poisoning (E850–869)	40	1.00	0.71–1.36
Falls (E880–888)	259	3.57[b]	3.15–4.03
Other injuries (E890–928)	225	1.63[b]	1.43–1.86
Suicide (E950–959)	260	0.99	0.87–1.12
Homicide (E960–978)	103	0.94	0.77–1.14
Others causes	224	0.59[b]	0.52–0.68

PMR, sproportionate mortality ratio.
[a]$p < 0.05$.
[b]$p < 0.01$.

TABLE VI. Observed Number of Deaths, Proportionate Cancer Mortality Ratios and 95% Confidence Intervals Among Ironworker Members Who Died 1984–1991

Causes of death (ICDA-9)	Observed no. of death	PCMR	95% confidence interval
All malignant neoplasms (140–208)	3,682	1.00	0.97–1.03
Buccal cavity and pharynx (140–149)	65	0.84	0.65–1.07
Digestive system (150–159)	764	0.86[b]	0.80–0.92
Esophagus (150)	82	0.89	0.71–1.11
Stomach (151)	117	1.03	0.85–1.23
Peritoneum and other digestive (158–159)	7	0.46[a]	0.18–0.95
Large intestine (152–153)	295	0.85[b]	0.75–0.94
Rectum (154)	51	0.82	0.61–1.08
Liver (155–156)	41	0.67[b]	0.48–0.91
Pancreas (157)	151	0.88	0.75–1.03
Respiratory system (160–165)	1,578	1.17[b]	1.11–1.23
Pleura and other parts of respiratory system (160, 163–165)	13	1.07	0.57–1.82
Trachea, bronchus, and lung (162)	1,523	1.18[b]	1.12–1.24
Larynx (161)	42	1.00	0.72–1.35
Breast (174–175)	2	0.37	0.04–1.35
Male genital organs (185–187)	339	0.87[b]	0.78–0.97
Kidney (189)	77	0.88	0.70–1.12
Bladder (188)	86	0.86	0.69–1.07
Other and unspecified sites (194–199)	307	1.18[b]	1.05–1.32
Skin (172, 173)	61	0.80	0.61–1.03
Brain and other central nervous system (191, 192)	70	0.82	0.64–1.04
Thyroid gland (193)	2	0.37	0.04–1.33
All lymphopoietic cancer (200–208)	304	0.91	0.81–1.02
Lymphosarcoma/reticulosarcoma (200)	21	0.96	0.59–1.47
Hodgkin's disease (201)	9	0.69	0.31–1.30
Other lymphatic neoplasms (202–203)	156	0.94	0.80–1.10
Leukemia and aleukemia (204–208)	114	0.89	0.74–1.07

PCMR, proportionate cancer mortality ratio.
[a]$p < 0.05$.
[b]$p < 0.01$.

elevated in the PMR analysis were the only causes of death that were found to be significantly elevated in the multiple cause analysis as well.

Years of Union Membership

Analyses were also conducted by years of union membership using the PMR and PCMR methodologies and examining diseases of specific interest among the Ironworkers (Table VII). There were statistically significantly increased risks for fatal injuries due to transportation injuries, falls, and other types of injuries, particularly in the earlier years of union membership. PMRs for falls were particularly elevated in the first 10 years (PMR = 8.36) and years 10–19 (PMR = 6.53) of union membership. After 40 years of union membership the risk for fatal falls remains highly elevated, but not statistically significant (PMR = 1.91), while the risk of transportation and other injuries declines.

Among those decedents with 10 or more years of union membership, there was an increased PMR for cancer of all sites combined which reached statistical significance for those members with 20–29 years of union membership and the positive trend continued to increase for those members with 30–39 years and for those members with >40 years. For lung cancer, the PMR was statistically significantly increased after 10 or more years of union membership but the positive trend seemed to decline after the 10- to 20-year interval. There were four deaths due to kidney cancer (PMR = 1.17) but these occurred among those members with 10 or fewer years in the union. No trends with years of union membership were observed for chronic nephritis, ischemic heart disease, hypertensive heart disease, or cerebrovascular disease.

Gender and Race

PMRs for falls, other injuries, all cancers, lung cancers, and cancers of other and unspecified sites were statistically significantly elevated among both white and nonwhite males.

The cohort included only 20 deaths among white females and only 1 death for a nonwhite female. The death for the nonwhite female was due to an injury. Six of the 20 deaths among white females were due to cancers (PMR = 0.98); 1 intestinal, 2 lung, 1 breast, 1 Hodgkin's disease, and 1 unspecified; two deaths were due to injury, five deaths were due to heart disease (PMR = 0.84) and three deaths were due to other diseases of the circulatory system (PMR = 1.47). No cause of death was found to be statistically significantly elevated.

Age at Death

Table VIII shows PMRs and PCMRs for selected causes by age at death. For fatal injuries the PMRs were significantly increased for each 10-year age period prior to age 60 for each category of fatal injury, with the exception of transportation injury for the age period less than 30. For all fatal injuries, the average age at death was 47 (median = 44) as compared to age 69 (median = 70) for all other causes of death combined, a statistically significant difference of 22 years. For all cancers and for cancers of the lung, PMRs were statistically significantly increased for each of the 10-year, age-of-death categories after age 50.

Skill Areas

Proportionate mortality analysis was conducted for each of the nine skill categories of Ironworkers which together comprised more than 98% of the study population (Table IX). We assigned a member to a particular skill category

TABLE VII. Observed Selected Causes of Death, Proportionate Mortality Ratios, or Proportionate Cancer Mortality Ratios by Years of Union Membership Among Ironworkers Who Died 1984–1991

	Years in the union											
	<10		10–19		20–29		30–39		40+		Total	
Causes of death (ICDA-9)	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**
Ischemic Heart Disease (410–414)	124	0.96	426	0.93	1,224	0.95[c]	1,283	0.93[c]	258	0.92[b]	3,315	0.94[c]
Hypertensive heart disease (402, 404)	6	1.06	21	1.32	44	1.15	40	0.99	11	1.36	122	1.12
Cerebrovascular disease (430–438)	22	0.84	66	0.74[b]	253	0.96	250	0.94	54	0.93	646	0.92[b]
NMRD[a] (460–519)	39	0.96	140	1.00	467	1.07	479	1.02	76	0.76	1,201	1.01
Chronic nephritis (580, 583, 585–587)	2	0.47	6	0.48	28	0.80	38	1.07	6	0.80	80	0.84
Transportation injury (E800–848)	148	1.18[b]	99	1.43[c]	72	1.34[b]	38	0.90	6	0.85	363	1.22[c]
Falls (E880–888)	69	8.36[c]	78	6.53[c]	58	2.37[c]	45	1.97[c]	9	1.91	259	3.57[c]
Other injuries (E890–928)	73	1.98[c]	58	1.91[c]	49	1.43[b]	39	1.28	6	0.90	225	1.63[c]
All cancers (140–208)	146	0.97	481	1.07	1,235	1.06[b]	1,489	1.12[c]	331	1.20[c]	3,682	1.09[c]
	OBS	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**
Lung cancer (162)	37	0.85	217	1.31[c]	525	1.23[c]	636	1.17[c]	108	0.93	1,523	1.18[c]
Kidney cancer (189.0–189.2)	4	1.17	6	0.53	31	1.12	28	0.90	8	1.32	77	0.88

[a]Nonmalignant respiratory disease.
[b]$p < 0.05$.
[c]$p < 0.01$.
OBS, observed selected cause of death; PCMR, proportionate cancer mortality ratio; PMR, proportionate mortality ratio.

TABLE VIII. Observed Selected Causes of Death Proportionate Mortality Ratios, or Proportionate Cancer Mortality Ratios by Age of Death Among Ironworkers Who Died 1984–1991

	Age at death															
	<30		30–39		40–49		50–59		60–69		70–79		80+		Total	
Causes of death (ICDA-9)	**OSB**	**PMR**	**OSB**	**PMR**	**OSB**	**PMR**	**OSB**	**PMR**	**OSB**	**PMR**	**OSB**	**PMR**	**OSB**	**PMR**	**OSB**	**PMR**
Ischemic heart disease (410–414)	2	0.96	23	0.87	100	0.78[b]	341	0.88[b]	812	0.90[b]	1,239	0.97	798	0.96	3,315	0.94[c]
Hypertensive heart disease (402, 404)	0	—	0	—	9	1.50	18	1.22	33	1.15	41	1.18	2	0.95	122	1.12
Cerebrovascular disease (430–438)	0	—	3	0.62	16	0.86	56	1.19	120	0.96	253	0.97	198	0.82	646	0.92[b]
NMRD[a] (460–519)	1	0.33	5	0.45	11	0.55	48	0.71	235	0.96	508	1.06	393	1.11	1,201	1.01
Chronic nephritis (582, 583, 585–587)	0	—	0	—	3	1.07	1	0.16	12	0.68	34	0.94	30	0.94	80	0.84
Transportation injury (E800–848)	82	1.01	91	1.28[b]	63	1.40[b]	55	1.57[b]	30	0.96	27	1.00	15	1.28	363	1.22[c]
Falls (E880–888)	32	10.71[c]	63	12.14[c]	52	10.42[c]	52	7.12[b]	23	2.07[c]	22	1.17	15	0.70	259	3.57[c]
Other injuries (E890–928)	28	1.53	52	2.12[c]	39	2.03[b]	41	1.98[b]	30	1.31	19	0.88	16	1.16	225	1.63[c]
All cancers (140–208)	12	0.92	50	1.09	134	0.98	497	1.11[b]	1,164	1.14[b]	1,252	1.08[b]	573	1.20[c]	3,682	1.09[c]
	OBS	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**	**OBS**	**PCMR**
Lung cancer (162)	1	3.21	7	1.20	45	1.06	229	1.13[b]	553	1.18[b]	515	1.18[b]	178	1.34[b]	1,523	1.18[c]
Kidney cancer (189.0–189.2)	1	14.08	1	1.52	2	0.23	20	1.38	19	0.65	26	0.98	8	0.77	77	0.88

[a]Nonmalignant respiratory disease.
[b]$p < 0.05$.
[c]$p < 0.01$.
OBS, observed selected cause of death; PCMR, proportionate cancer mortality ratio; PMR, proportionate mortality ratio.

TABLE IX. Observed Selected Causes of Death, Proportionate Mortality Ratios by Skill Codes Among Ironworkers Who Died 1984–1991

	Skills																	
	Shopman		Ironworker		Structural Ironworker		Rodman		Finisher		Rigger Machine		Stone Derrickman		Sheeter		Welder	
Causes of death (ICDA-9)	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR	OBS	PMR
All causes (000–999)	2,801	1.00	6,346	1.00	461	1.00	1,617	1.00	441	1.00	505	1.00	24	1.00	139	1.00	752	1.00
All cancers (140–208)	713	1.04	1,708	1.08[c]	124	1.03	499	1.15[c]	130	1.16	152	1.19[b]	5	0.83	45	1.16	237	1.15[b]
Lung cancer (162)	266	1.14[b]	719	1.30[c]	56	1.24	212	1.33[c]	57	1.45[c]	71	1.59[c]	3	1.41	17	1.15	92	1.23
Kidney cancer (189.0–189.2)	19	1.22	32	0.85	2	0.60	5	0.47	5	1.87	1	0.34	0	—	2	2.03	7	1.46
Ischemic heart disease (410–414)	813	1.07	1,543	0.92[c]	87	0.83	386	0.89[c]	106	0.88	116	0.82[b]	5	0.78	27	0.73	190	0.91
Hypertensive heart disease (402, 404)	43	1.76[b]	51	1.02	6	1.56	11	0.82	4	1.13	2	0.49	0	—	0	—	4	0.65
Cerebrovascular disease (430–438)	155	0.94	317	0.95	16	1.04	62	0.77[b]	19	0.79	25	0.85	6	4.65[c]	9	1.52	27	0.69[b]
NMRD[a] (460–519)	298	1.11	549	0.97	21	0.83	153	1.10	36	0.89	53	1.07	1	0.46	8	0.75	71	1.02
Chronic nephritis (582, 583, 585–587)	14	0.62	44	0.97	2	0.91	7	0.64	4	1.25	3	0.77	0	—	1	1.25	3	0.57
Transportation injury (E800–848)	46	0.99	189	1.22[c]	40	1.73[c]	39	1.25	9	1.10	8	1.13	1	1.79	5	1.43	16	1.62
Falls (E880–888)	14	0.88	171	4.86[c]	19	6.98[c]	21	2.57[c]	9	3.74[c]	2	0.76	0	—	5	7.46[c]	13	3.74[c]
Other injuries (E890–928)	29	1.17	132	1.92[c]	15	1.67	23	1.47	2	0.49	6	1.55	2	8.24	1	0.64	10	1.76

[a]Nonmalignant respiratory disease.
[b]$p < 0.05$.
[c]$p < 0.01$.
OBS, observed selected cause of death; PMR, proportionate mortality ratio.

TABLE X. Observed Selected Causes of Death, Proportionate Mortality Rates, by Types of Locals Among Ironworkers Who Died, 1984–1991

	Type of local																					
	AO		M		MR		O		R		S		SD		SH		SMR		SO		YR	
Causes of death (ICDA-9)	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**	**OBS**	**PMR**
All causes (000–999)	142	1.00	7,960	1.00	199	1.00	197	1.00	474	1.00	596	1.00	23	1.00	2,689	1.00	526	1.00	465	1.00	28	1.00
All cancers (140–208)	47	1.29	2,254	1.10[c]	57	1.14	52	1.11	156	1.29[c]	152	1.01	5	0.87	679	1.03	146	1.10	123	1.04	11	1.69
Kidney cancer (189.0–189.2)	2	2.27	49	1.00	0	—	1	0.90	1	0.34	2	0.56	0	—	18	1.20	1	0.32	3	1.06	0	—
Lung cancer (162)	21	1.61	976	1.35[c]	24	1.38	21	1.32	55	1.27	56	1.05	3	1.48	254	1.13[b]	56	1.20	53	1.25	4	1.74
Ischemic heart disease (410–414)	30	0.81	1,896	0.90[c]	51	1.05	51	0.95	91	0.75[c]	171	1.06	5	0.81	794	1.09[b]	112	0.82[b]	111	0.91	3	0.46
Hypertensive heart disease (402, 404)	1	0.87	63	0.99	2	1.23	2	1.28	1	0.25	3	0.60	0	—	39	1.66[c]	6	1.48	5	1.33	0	—
Cerebrovascular disease (430–438)	9	1.27	368	0.90[b]	6	0.54	11	0.97	19	0.81	29	0.90	6	4.88[c]	148	0.94	27	1.01	22	0.93	0	—
NMRD[a] (460–519)	12	0.97	700	1.00	15	0.82	12	0.65	37	0.95	47	0.87	1	0.48	285	1.11	60	1.30	30	0.76	2	0.92
Chronic nephritis (582, 583, 585–587)	1	1.02	49	0.90	2	1.36	2	1.33	3	0.94	3	0.68	0	—	13	0.60	2	0.57	3	0.95	0	—
Transportation injury (E800–848)	0	—	254	1.37[c]	4	0.91	6	1.37	18	1.26	8	0.74	1	1.81	44	0.96	18	1.20	8	0.65	2	2.47
Falls (E880–888)	4	5.18[b]	197	4.62[c]	0	—	2	1.73	1	0.38	13	3.93[c]	0	—	13	0.85	14	4.91[c]	15	5.89[c]	0	—
Other injuries (E890–928)	2	1.33	154	1.82[c]	3	1.52	2	1.01	9	1.52	11	1.96	2	8.40[b]	28	1.16	12	1.95	2	0.38	0	—

[a]Nonmalignant respiratory disease.
[b]$p < 0.05$.
[c]$p < 0.01$.
AO, Architectural and Ornamental Ironworker; M, Mixed; MR, Machinery Mover, Erectors, and Riggers; O, Ornamental Ironworker; R, Rodman; S, Structural Ironworker; SD, Stone Derrickman; SH, Shopman; SMR, Structural, Machine Movers, and Riggers; SO, Structural and Ornamental Ironworker; YR, Navy Yard Riggers.
OBS, observed selected cause of death; PMR, proportionate mortality ratio.

based on the majority of time he worked in that skill; however, a member's movement from one skill category to another was infrequent. For those causes of death due to injury, the skill category of ironworker had statistically significantly increased PMRs for all types of injuries (transportation, falls, and all other injuries). Similarly, statistically significantly increased PMRs for the skill category structural ironworker were observed for transportation injuries and falls, with ''other injuries'' highly elevated but not statistically significant. Rodmen, finishers, and welders had statistically significantly increased risks for fatal falls.

PMRs for all cancers were significantly elevated in five of the nine skill categories and elevated in three of the remaining four others. For lung cancer, a statistically significant elevation was observed for six skill categories and increased in the other three.

Type of Local

The PMRs for falls were significantly elevated for the local classifications of mixed, architectural and ornamental, ornamental, structural, machine movers and riggers, and structural and ornamental (Table X). The PMRs for all cancers combined and for lung cancer were elevated for each classification of local union, with the exception of stone derrickmen for all cancers combined.

DISCUSSION

The most notable risk documented in the study was due to fatal falls, for which the PMR was significantly elevated throughout the years of working life. Other significant elevations were found for other types of injuries, lung cancer, and pneumoconioses and other respirable disease.

Fatal Injuries

Results from this study were similar to previous studies and surveillance data among construction workers, in general, and ironworkers, specifically, which have documented excess deaths from occupational injuries, falls in particular. A NIOSH study of occupational-coded death certificates of work-related injuries from 19 states found that fatal injuries due to falls were the leading cause of death among construction workers [Robinson et al., 1995]. In the subset of structural metal workers from this study, results showed a PMR of 517 for ''falls on or from ladders and scaffolds,'' a PMR of 1,590 for ''falls from or out of structures,'' and a PMR of 315 for ''struck by falling object.'' All these findings were statistically significant at $p < 0.01$. In an update to this study examining results from 24 states, Burnett (personal communication, NIOSH) found a significantly elevated risk among structural metal workers for all injuries (PMR = 1.26, CI = 1.11–1.42) and for all falls (PMR = 3.33 (CI = 2.36–4.57). Parsons [1989] examined the risk of nonfatal and fatal injuries among occupations within the construction industry and observed that structural metal workers had the fourth highest composite occupational risk index (nonfatal injuries) and second highest fatality index (fatal injuries) and, taking both indexes into account, found that structural metal workers had the highest risk factor index (total lost work days) among all occupations examined within the construction industry. Forty-nine percent of all fatal injuries among the structural metal workers were due to falls from scaffolds and ladders into shafts and onto lower levels. In a study of all deaths from the construction industry from the state of New Jersey for 1983–1989, Sorock et al. [1993] found that construction workers as a whole had 3.2 times the rate of fatal injury than all industries combined, i.e., 14.5 per 100,000 person-years, and that Ironworkers as a group had the highest rate of fatal injury among all construction occupations, i.e., 109.0 per 100,000 person-years. The leading cause of death was falls (46%). The Bureau of Labor Statistics 1993 Census of Fatal Occupational Injuries reported that 9% of all work-related fatal injury were in the construction industry and construction trades workers were injured at a rate of 11 per 100,000 workers. Structural metal workers had the highest rate of fatal injury within the construction industry with 76 per 100,000 workers [USDOL, 1993]. In a study of fatal falls for the years 1984–1988 using the NIOSH National Traumatic Occupational Fatality (NTOF) database, Fosbroke (personal communication, NIOSH, Division of Safety Research) found 158 fatal falls in workers employed in structural steel erection, a rate of 54.8 deaths per 100,000 person-years, 9 times the rate of the construction industry as a whole and 90 times the rate of all industries combined. The heights of the fatal falls were known for 60% of the deaths and more than 36% of those occurred at heights below 30 feet. Although data from the NTOF surveillance system have shown that deaths from falls in the construction industry have declined 21.1% from 1980–1989, falls were still an important cause of occupational mortality with 5.6 deaths per 100,000 workers in 1989 [Stout et al., 1996].

The average age at death in our study for fatal injuries was 47 (median = 44) as compared to 69 (median = 70) for all other causes of death. Since traumatic deaths are responsible for many more years of potential life lost than are disease-related deaths [CDC, 1986], these results have added significance. The results from our study clearly underscore the critical need to reduce workplace fatalities among this occupational group. Use of effective fall protection, as is now mandated by the OSHA construction standard, will substantially reduce the risk of fatal falls in the construction industry. Other long-term measures include use of hearing protection [Kilburn et al., 1992] and active programs to promote health and safety at the worksite [CPWR, 1995].

Lung Cancer

We observed a slight but statistically significant elevation in the PMR for total malignant neoplasms, a large part

of which was due to a statistically significantly increased mortality ratio for cancer of the lung. A previous study examining more than 61,000 deaths among construction workers observed that both construction workers, in general, and Ironworkers, specifically, had elevated PMRs for lung cancer [Robinson et al., 1995]. Lung cancer in the construction industry may be associated with the use of welding fumes, asbestos, coal tar pitch, asphalt production, and diesel exhaust among other agents [NIOSH, 1988; Hammond et al., 1976; Silverstein et al., 1985; Steenland et al., 1990; Steenland, 1986; Wilson, 1984; Schenker, 1980; NIOSH, 1977]. Construction Ironworkers may come into contact with these agents in either their normal assignments or by working in close contact with other construction tradesmen.

Welding is one of the job skills that all journeymen Ironworkers are required to know and approximately 60% of all union Ironworker members actually perform welding on the job (James Cole, Ironworkers union, personal communication). Welders have been found to have a significantly increased risk of respiratory cancer, as high as 40% [NIOSH, 1988]. In this study, a statistically significant excess risk of lung cancer among six of the nine skill categories of Ironworkers, including welder (PMR = 1.23), was observed. Eighty-seven of the 92 lung cancer deaths among the skill category welder occurred after a latency period of 20 years. Therefore, exposure to welding fumes would be a potential cause of the elevated risk of lung cancer observed in this study.

Some studies suggest that construction workers as a whole are at an increased risk of asbestos-related lung diseases due to their exposure to asbestos either directly, in the tasks they perform, or indirectly, by working in close proximity to other skilled tradesmen who are exposed to asbestos on their jobs [Selikoff, 1969]. In a clinical study of Ironworkers from the New York metropolitan area, Fischbein et al. [1991] found that 38% of the examined workers had pleural abnormalities consistent with asbestos induced effects. Further analysis showed that length of employment in the Ironworkers' trade was the most important factor associated with those pleural abnormalities. The report stated that ''in the past, application of insulation materials containing asbestos on iron and steel structures by spraying was frequently performed in the Ironworkers' environment with subsequent risk for excessive exposure'' [Fischbein et al., 1991]. Kilburn et al. [1986] found that of 11 building trades studied, Ironworkers had the third highest prevalence of asbestosis—21.8%. The occurrence of seven deaths due to mesothelioma as the underlying cause of death and 35 other death certificates which mentioned mesothelioma, as well as 10 additional deaths due to asbestosis as the underlying cause of death, are consistent with prior studies in demonstrating potential asbestos exposure for at least a portion of this cohort. The asbestos exposure may have contributed to the lung cancer excess as well. Even though use of asbestos in new buildings is now banned, exposure to asbestos is not a thing of the past. In demolition, conversions, and repairs, Ironworkers will be exposed to asbestos for years to come.

It has been suggested that workers in the construction industry may have a greater risk of smoking-related diseases because of their excessive smoking experience [Walrath et al., 1985; Hrubec et al., 1992] and the potential synergistic effects between smoking and various exposures among these workers. Information on smoking status or amount of cigarette smoking among members of this group of Ironworkers was not available and, therefore, it is unknown what effect, if any, smoking may have contributed to our results. Most of the PMR results for those diseases associated with smoking, other than lung cancer, were approximately equal to 1.0.

Renal Effects and Cerebrovascular Disease

Before conducting this study, we hypothesized that Ironworkers might have an excess risk of lead-related diseases. Some Ironworkers may be exposed to high lead concentrations in lead-containing paint that was used in the past to inhibit rust and corrosion during demolition or restoration of metal structures, such as bridges [Katauskas, 1990]. Operations such as abrasive blasting, sanding, burning, cutting, or welding to remove the paint or cut through structural iron, can generate lead fume or lead particles. Causes of death likely to be elevated in a cohort study of lead-exposed workers include chronic renal disease, cerebrovascular disease, and renal cancer [Steenland et al., 1992]. None of these causes was significantly elevated in the overall group or in any of the sub-analyses by skill code or local type. The most likely explanation for the absence of elevation in lead-related causes of death are that only a relatively small proportion of the cohort is exposed to lead, and that lead exposure is not strongly associated with a particular skill category or local.

Strengths and Limitations

Like all epidemiologic studies, this study has some potential strengths and limitations that should be considered. The representativeness of the group studied relative to all members in the Ironworkers union was a strength. Part of the local dues that an Ironworker was required to contribute went to the International union to pay into the death beneficiary fund. Even when a worker retired, he still was required to pay into the death beneficiary fund although at a reduced amount. Therefore, as long as an Ironworker was actively part of the union, he had to contribute to the death fund. The number of members who left the union and stopped paying dues was relatively small because the expense required to rejoin the union was considerable.

However even for those who left, there was no reason to assume that they were any different from those members who stayed (Jim Bonnano, IABSOI, personal communication). Therefore, it was felt that the deceased members of this study were an unbiased sample of the entire Ironworkers population at risk.

Another strength is that studies comparing PMRs with SMRs have shown that PMRs are useful indicators of disease risk showing a high correlation with SMRs in most cases, and especially when there is a financial interest for survivors to report deaths among workers, as was the case in this study [Roman et al., 1984; Beaumont et al., 1981; St. Claire et al., 1981].

The data in this study are based on the Ironworkers' union records with its available occupational information. This is far better than information found on death certificates which is usually reported by a survivor and can reflect recall bias.

Another strength to this study is that we chose all deaths for 1984–1991 among those members of the International Association of Bridge, Structural, and Ornamental Ironworkers (IABSOI) as our study population. This had a number of positive features: (1) the IABSOI is the largest single group of Ironworkers in the world; (2) the number of deaths in the study (more than 13,000) had sufficient power for examining the results from most causes of death (80% power of detecting a minimum relative risk of 2.0); (3) the deaths from 1984–1991 were the most recent and, therefore, the most representative of both current and past work practices and exposures of ironworkers; and (4) all membership data had been computerized since 1984 making the study more accurate, as well as more efficient to complete.

Another aspect of PMR studies, and this study in particular, is that members who terminate their employment prior to retirement or death are not included in the analyses. It has been shown [Fox et al., 1976; Redmond et al., 1975] that these individuals tend to have different mortality patterns than individuals who remain employed through retirement. In active and retired employees, relatively fewer cancer deaths are found as compared with terminated employees because cancer deaths are not sudden and cancer patients will usually leave employment some time before death. Therefore, it is possible that malignant neoplasms were underestimated in our study since workers who left the union before retirement or death were not included in our analyses.

A potential limitation in the PMR methodology is that the magnitude of each cause of death is dependent on the magnitude of the PMRs for other causes of death. This can be especially important if a specific common cause has a relatively high or low mortality. Typically in a working population, the risk of heart disease is lower than expected due to the so-called ''healthy worker effect'' and, therefore, in a PMR study the other causes would be artificially elevated. In this study, the risk of heart diseases had a significantly low PMR of 0.95, with 4,575 observed deaths and 4,838 expected deaths. However, this difference of 263 deaths spread over 92 causes would have tended to only slightly increase the PMRs for the other remaining causes of death.

Exposures in this study were not monitored, since local unions, in general, did not track sites or specific job tasks performed when an Ironworker was dispatched to a particular construction job. The types, intensity, and length of exposures of the specific members were therefore unknown.

PMR study results are based on death certificate data, which have little information on potential confounding factors such as tobacco, alcohol use, and socioeconomic status. Finally, multiple significance testing may have resulted in associations that arose from chance alone.

SUMMARY AND RECOMMENDATIONS

Our results among 13,301 members of the International Association of Bridge, Structural, and Ornamental Ironworkers analyzed in this study confirm earlier findings of increased risk of death from fatal injuries and lung cancer among Ironworkers. The elevated risks of fatal injuries were undoubtedly due to the types of jobs Ironworkers are required to perform, the heights at which these activities occur, and the failure of employers to provide adequate fall protection devices. The excess lung cancer risk was probably directly due to welding fumes and asbestos exposure, and/or possibly indirectly due to exposure to coal tar pitch, asphalt production, diesel exhaust, or some other toxic agent. Excess cigarette smoking, however, cannot be entirely ruled out as a confounding variable in these latter results.

Based on the results of this study, additional research on the potential causes and prevention of injuries among Ironworkers is recommended. Such studies are necessary to identify risk factors and to assist in the development and targeting of injury prevention and intervention strategies. The use of fall protection in the construction industry is a potentially important preventative measure for which governmental regulations continue to evolve [BNA, Article No. 22231405, 1995]. Other recommendations from this study include reducing exposures to welding fumes to the lowest feasible concentration using state-of-the-art engineering controls and work practices, reducing workers' exposure to asbestos during renovation and demolition work, developing programs to encourage the use of hearing protection, and developing labor–management health and safety programs to identify health and safety hazards.

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REFERENCES

Beaumont J, Lee TL, Okun AH (1981): Occupational data sets appropriate for proportionate mortality ratio analysis. Banbury Report 9: ''Quantification of Occupational Cancer,'' pp 391–411.

Bureau of Labor Statistics (1993): ''Employment and Earnings, Household Data Annual Averages.'' Washington, DC: US Government Printing Office US Department of Labor, 37(1).

California Department of Health (1987): ''California Occupational Mortality (COM) 1979–1981.''

Centers for Disease Control (1986): Premature mortality due to unintentional injuries—United States, 1983. MMWR 35:353–356.

Center to Protect Workers' Rights (1995): Advancing the Agenda for Safety and Health. Report of the 1994 Regional Conference on Ergonomics, Safety, and Health in Construction. Report G2-95. Washington, DC.

DeCouflé P, Thomas T, Pickle L (1980): Comparison of the proportionate mortality ratio and the standardized mortality ratio risk measures. Am J Epidemiol 111:263–269.

Fischbein A, Luo J, Rosenfeld S, Lacher M, Miller A, Rosenbaum A. (1991): Respiratory findings among ironworkers; results from a clinical survey in the New York metropolitan area and identification of health hazards from asbestos in place at work. Br J Ind Med 48:404–411.

Fox A, Collier P (1976): Low mortality rates in industrial cohort studies due to selection for work and survival in the industry. Br J Prev Soc Med 30:225–230.

Hammond C, Selikoff J, Lawther P (1976): Inhalation of benzopyrene and cancer in man. Ann NY Acad Sci 271:116–124.

Hrubec Z, Blair B, Rogot E, Vaught J (1992): ''Mortality Risks by Occupation Among U.S. Veterans of Known Smoking Status 1954–1980.'' NIH Publ. No. 92-3407, DHHS (PHS) Bethesda, MD.

Katauskas T (1990): R & D special report: DOT coats rusting bridges with layers of problems. R&D May:42–48.

Kilburn H, Lilis R, Anderson HA, Miller A, Warshaw RH (1986): Interaction of asbestos, age, and cigarette smoking in producing radiological evidence of diffuse pulmonary fibrosis. Am J Med 80:377–381.

Kilburn H, Warshaw R, Hanscom B (1992): Are hearing loss and balance dysfunction linked in construction iron workers? Br J Ind Med 49:138–141.

National Institute for Occupational Safety and Health (1988): ''Criteria for a Recommended Standard. Welding, Brazing and Thermal Cutting.'' DHHS (NIOSH) Publ. No. 88-110. Washington, D. C.

National Institute for Occupational Safety and Health (1988,1990a,b): ''National Occupational Exposure Survey.'' DHHS(NIOSH) Publ Nos. 88–106, 89–103. Washington, D.C.

National Institute for Occupational Safety and Health (1977): ''Criteria for a Recommended Standard. Occupational exposure to asphalt fumes.'' DHEW (NIOSH) Pub no. 78-106, Washington, DC: U.S. Government Printing Office.

Parsons T (1989): ''Establishment of a Construction Safety Research Plan for NIOSH/DSR.'' NTIS PB89165187.

Redmond C, Breslin P (1975): Comparison of methods for assessing occupational hazards. J Occup Med 17:313–317.

Robinson C, Stern F, Halperin W, Venerable H, Petersen M, Frazier T, Burnett C, Lalich N, Sestito J, Fingerhut M (1995): Assessment of mortality in the construction industry in the United States, 1984–1986. Am J Ind Med 28:49–70.

Roman E, Beral V, Inskip H, McDowell M, Adelstein A (1984): A comparison of standardized and proportional mortality ratios. Stat Med 3:7–14.

Rothman KJ, Boice JD (1979): ''Epidemiologic Analysis with a Programmable Calculator.'' Washington, DC: Department of Health and Human Services, 30-31, NIH Publ. No. 79-1649.

Schenker MB (1980): Diesel exhaust—an occupational carcinogen? J Occup Med 22:41–46.

Selikoff IJ (1969): Asbestos. Environment 11:3–7.

Selikoff IJ, Churg J, Hammond EC (1965): Relation between exposure to asbestos and mesothelioma. N Engl J Med 272:560–565.

Silverstein M, Maizlish N, Park R, Mirer F (1985): Mortality among workers exposed to coal tar pitch volatiles and welding emissions: An exercise in epidemiologic triage. Am J Public Health 75:1283–1287.

Singleton JA, Beaumont JJ: ''Coms II (1989): California Occupational Mortality, 1979–1981.'' California Department of Health Services.

Sorock G, Smith E, Goldoft M (1993): Fatal occupational injuries in the New Jersey construction industry, 1983–1989. J Occup Med 35:916–921.

St. Claire, Butler W (1981): ''A review of Proportionate Mortality Design in Occupational Epidemiology.'' Paper presented at the American Public Health Association annual meeting, Los Angeles, November 5, 1981.

Steenland K, Beaumont J, Spaeth S, Brown D, Okun A, Jurcenko L, Ryan B, Phillips S, Roscoe R, Stayner L, Morris J (1990): New developments in the life table analysis system of the National Institute for Occupational Safety and Health. J Occup Med 32:1091–1098.

Steenland K (1990): Case control study of lung cancer and truck driving in the Teamsters Union. Am J Ind Med 80:670–674.

Steenland K (1986): Lung cancer and diesel exhaust: A review. Am J Ind Med 10:177–189.

Steenland K, Nowlin S, Ryan B, Adams S (1992): Use of multiple-cause mortality data in epidemiologic analyses: US rate and proportion files developed by the National Institute for Occupational Safety and Health and the National Cancer Institute Am J Epidemiol 136:855–862.

Stout N, Jenkins E, Pizatella T (1996): Occupational injury mortality rates in the United States: Changes from 1980 to 1989. Am J Public Health 86:73–77.

U.S. Department of Labor. Bureau of Labor Statistics (1993): ''Occupational injuries and illnesses in the United States by industry.'' Bulletin 2236.

Walrath J, Rogor E, Murray J, Blair A (1985): ''Mortality Patterns Among U.S. Veterans by Industry and Smoking Status.'' NIH Publ. No. 85-2747, DHHS (PHS) Bethesda, MD.

Wilson K (1984): Asphalt production and lung cancer in a Danish village. Lancet 2:354.

World Health Organization (WHO) (1977): ''International Classification of Diseases. Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death.'' Based on the recommendations of the Ninth Revision Conference, 1975. Geneva: WHO.