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Assessment of Mortality in the Construction Industry in the United States, 1984–1986

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Construction, one of the larger industries in the United States, employs 7.6 million workers, many in skilled trades occupations. Previously published data about potential worksite exposures and mortality of construction site workers are limited. We analyzed occupation and industry codes on death certificates from 19 U.S. states to evaluate mortality risks among men and women usually employed in construction occupations. Proportionate mortality ratios (PMRs) for cancer and several other chronic diseases were significantly elevated among 61,682 white male construction workers who died between 1984 and 1986. Men younger than age 65, who were probably still employed immediately prior to death, had significantly elevated PMRs for cancer, asbestos-related diseases, mental disorders, alcohol-related disease, digestive diseases, falls, poisonings, traumatic fatalities that are usually work-related, and homicides. Elevated PMRs for many of the same causes were observed to a lesser degree for black men and white women whose usual industry was construction. In addition, women experienced excess cancer of the connective tissue and suicide mortality. Various skilled construction trades had elevated PMRs for specific sites, such as bone cancer and melanoma in brickmasons, stomach cancer in roofers and brickmasons, kidney and bone cancer in concrete/terrazzo finishers, nasal cancer in plumbers, pulmonary tuberculosis in laborers, scrotal cancer and aplastic anemia in electricians, acute myeloid leukemia in boilermakers, rectal cancer and multiple sclerosis in electrical power installers, and lung cancer in structural metal workers. Using a standard population of blue collar workers did not result in fewer elevated PMRs for construction workers. Despite lifestyle differences and other limitations of the study, the large numbers of excess deaths observed in this study indicate the need for preventive action for construction workers.

Key words: mortality surveillance, occupational health, occupational disease, construction industry, skilled trades occupations, carpenters, electrical workers, silicosis, asbestosis, blue collar workers

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INTRODUCTION

Construction is one of the larger industries in the United States, employing 7.6 million workers in 1992 [U.S. Census, 1992], yet published studies about potential worksite exposures and health of construction workers are limited. This may be due partially to the difficulty of studying construction workers, because of the lack of centralized personnel and medical records. Also, construction workers change jobs frequently because worksites are temporary and change constantly as the work moves ahead. Both skilled trades people and unskilled workers may be employed on construction worksites, involved in the construction, renovation, repair, or demolition of residential or industrial buildings, bridges, roads, ships, or tunnels. Each occupation or special trade may have unique health and safety risks specific to its tasks and work practices. In addition, several trades people and unskilled workers may share a work area, exposing each other as "bystanders" to toxic substances. Thus construction worksites present special problems in the study, identification, and control of health hazards.

In the tradition of William Farr, founder of modern surveillance [Langmuir 1976], we have characterized the mortality risks of construction workers using death certificates coded for usual occupation. We undertook the present analysis because death certificates coded by occupation and industry for the last decade from many U.S. states recently became available. This permitted evaluation of rare causes of death for recent years for skilled trades and construction laborers. We reviewed previously published reports in the context of our study results. Our goals were to provide estimates of the mortality experience of construction workers, to form hypotheses for further research, and to identify and prevent hazardous occupational exposures.

PREVIOUS REPORTS

Construction workers in building, highway, and special trades have been reported previously to experience excess mortality from cancer and from circulatory, respiratory, nervous, and digestive system disease and fatalities (Registrar 1978, 1986; Milham 1983; COMS, 1987). The Registrar General's Decennial Supplement on occupational mortality 1970–72 for England and Wales [Registrar, 1978] reported statistically significant excess deaths due to cancer of the esophagus, rectum, larynx, and lung for all construction workers. In 1986, significant excess risk was reported for cancer of the esophagus, rectum, and lung and for falls [Registrar, 1986]. In the United States, a proportionate mortality ratio (PMR) study of deaths occuring during the years 1950–1979 in Washington State [Milham, 1983] found that men working as construction laborers had significant excess mortality due to respiratory tuberculosis; cancer of larynx, lung, bladder, and connective tissue; disorders of character, behavior, and intelligence; other respiratory disease; accidental falls; cirrhosis of the liver; and homicide. California construction industry workers who died from 1979 through 1981 were reported to have excess deaths due to cancer of lip, oral cavity, pharynx, lung, urinary organs, and other digestive organs, ischemic heart disease, stroke, cirrhosis, chronic obstructive lung disease, falls, and suicide [COMS, 1987]. Swedish construction workers who participated in the Bygghalsan program of regular voluntary medical exams were found to have significant excess cancer of the lung, larynx, and gastrointestinal tract [Englund, 1981; Fletcher, 1990]. The fatality rate

for the U.S. construction industry has been reported from the National Traumatic Occupational Fatality surveillance project to be 25.61 per 100,000 workers for 1980–1989 [NIOSH, 1993], ranking construction as the second most hazardous industry in terms of traumatic fatalities.

In addition to the raised PMRs reported above for all construction industry workers, differentials in mortality risk have been reported for various skilled trades within the construction industry. Table I compares PMRs observed for selected skilled trades by two of the larger previous reports, England and Wales 1979–1983 [Registrar, 1986] and Washington State 1970–1979 [Milham, 1983]. Only PMRs that were significantly elevated in at least one of the two reports are shown. Most striking were the similarly elevated PMRs across many trades for excess mortality due to all cancer, respiratory cancer, mental disorders, liver disease and cirrhosis, respiratory disease mortality, and traumatic fatalities.

MATERIALS AND METHODS

Data Sources

We analyzed occupation and industry-coded U.S. death certificate data for the years 1984–1986. The data were pooled from 19 states in the United States, which together with the National Institute for Occupational Safety and Health (NIOSH), National Center for Health Statistics, and National Cancer Institute have shared the added costs of coding occupation and industry on their death certificates. The 19 states are Colorado, Georgia, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Mexico, Ohio, Oklahoma, Rhode Island, South Carolina, Tennessee, Utah, Vermont, and Wisconsin. About 6% of the U.S. employed population worked in the construction industry, and most of the 19 states in our study were representative of the overall United States. Only one state differed by more than 2%; this was New Mexico, where 9% were employed in the construction industry [U.S. Census, 1982].

Identification of Construction Industry Workers and the Trades

Death certificates for decedents age 20 and over who both resided and died in one of the 19 states were the source of age, sex, race, usual occupation and industry, and underlying cause-of-death. Occupation and industry entires on 876,731 death certificates (560,370 white men, 69,564 black men, 214,647 white women, and 32,150 black women) were provided by the states to NIOSH. Housewives, the unemployed, part-time workers, and unknown occupations were excluded from the analysis. Coding of usual occupation and industry stated on the death certificate by next-of-kin was done by clerks trained in procedures developed by the Bureau of the Census for NIOSH and NCHS [NCHS, 1987]. Table II shows the occupation codes used to select the skilled trades, the laborers, and the code for the construction industry [U.S. Census, 1980].

The skilled construction trades included painters, plumbers, insulators, bricklayers, carpenters, operating engineers, elevator installers, electricians, roofers, structural metal workers, concrete and terrazzo finishers, electrical power installers and repairers, operating engineers, tile setters, carpet installers, plasterers, boilermakers, and drywall installers. The unskilled trades included construction laborers (Table II).

The mortality experience of construction workers was compared first with all

TABLE I. Comparison of Construction Trade Mortality Reports for England and Wales, 1979–1983, and Washington State, 1970–1979

	England and Wales		Washington State	
Causes of death[a]	No. deaths	PMR[b]	No. deaths	PMR[b]
Carpenters (554, 561, 569[c]) (411[d])				
Malignant neoplasms (MN) (140–208)	3771	105[f]	1070	101
MN nose, middle ear, sinuses (160)	7	136	6	296[f]
MN pleura (163)	47	361[f]	2	85
MN prostate (185)	219	121[f]	139	108
MN lymphatic and hematopoietic tissue (200–208)	250	115[e]	91	93
Mental disorders (290–319)	59	137[e]	4	241
Chronic obstructive pulmonary disease and allied conditions (490–496)	457	85	280	116[e]
Diseases of esophagus (530)	14	186[e]	NR[g]	–
Fatalities due to falls (880–888, 9293)	96	165[f]	73	149[f]
Electricians (555, 575, 576[c]) (421[d])				
Malignant neoplasms (MN) (140–208)	2385	105[e]	428	104
MN stomach (151)	229	115[e]	17	99
MN pleura (163)	38	406[f]	2	–
Acute myeloid leukemia (2050)	34	149[e]	4	154
Painters, paperhangers (556, 579, 583[c]) (694[d])				
Malignant neoplasms (MN) (140–208)	3706	106[f]	405	106
MN trachea, bronchus, and lung (162)	1754	123[f]	150	118[e]
Mental disorders (290–319)	60	139[e]	9	113
Chronic obstructive pulmonary disease and allied conditions (490–496)	606	115[f]	116	138[f]
Chronic liver disease and cirrhosis (571, 5721–5728)	58	73[e]	53	152[f]
External causes of injury and poisoning (800–999)	664	111[e]	140	91
Railway accidents (800–807)	8	50[e]	1	–
Unintentional poisonings (850–869, 9292)	46	198[f]	NR	–
Unintentional poisonings by drugs, medicaments and biologicals (850–858)	35	273[f]	NR	–
Fatalities due to falls (880–888, 9293)	94	163[f]	19	117
Suicide and self inflicted injury (950–959)	218	127[f]	34	93
Plasterers (584[c]) (505[d])				
Malignant neoplasma (MN) (140–208)	744	115[f]	58	120
MN trachea, bronchus, and lung (162)	364	138[f]	24	161[e]
Chronic obstructive pulmonary disease and allied conditions (490–496)	155	158[f]	18	173[e]
Plumbers, pipefitters (557, 585, 587[c]) (510[d])				
Malignant neoplasms (MN) (140–208)	2079	112[f]	383	118[e]
MN esophagus (150)	28	127	16	235[f]
MN trachea, bronchus, and lung (162)	908	121[f]	134	122[e]
MN pleura (163)	32	428[f]	1	–
Chronic obstructive pulmonary disease and allied conditions (490–496)	298	111	93	132[f]

(continued)

TABLE I. *(Continued)*

Causes of death[a]	England and Wales		Washington State	
	No. deaths	PMR[b]	No. deaths	PMR[b]
Glaziers, roofers (589, 595[c]) (514[d])				
Malignant neoplasms (MN) (140–208)	456	111[e]	66	102
MN trachea, bronchus, and lung (162)	221	139[f]	35	157[f]
Chronic liver disease and cirrhosis (571, 5721–5728)	10	83	19	225[f]
External causes of injury and poisonings (800–999)	217	145[f]	57	103
Fatalities due to falls (880–888, 9293)	62	611[f]	4	127
Laborers, construction (869[c]) (982[d])				
Pulmonary tuberculosis (011)	22	152	2	127
MN trachea, bronchus, and lung (162)	958	122[f]	151	116
MN penis and other male genital organs (187)	8	259[e]	NR	–
Mental disorders (290–319)	46	165[f]	16	164[e]
Cerebrovascular disease (430–438)	604	115[f]	NR	–
Pneumonia and influenza (480–487)	346	133[f]	41	92
Chronic obstructive pulmonary disease and allied conditions (490–496)	346	125[f]	102	128[e]
Peptic ulcer (531–534)	69	143[f]	6	123
Chronic liver disease and cirrhosis (571, 5721–5728)	48	92	121	148[f]
External causes of injury and poisoning (800–999)	487	105	309	118[f]
Motor vehicle fatalities (810–825, 9290)	112	78	116	122[e]
Fatalities due to falls (880–888, 9293)	66	173[f]	32	173[f]
Injury undetermined whether accidentally or purposely (980–989)	65	151[f]	NR	–

[a]*International Classification of Diseases*, 9th rev. Geneva: WHO, 1978.
[b]Proportionate mortality ratio.
[c]Occupation codes for United States and England and Wales based on occupation codes from the US Bureau of Census, 1980 Census of Population, Alphabetical Index of Industries and Occupation, Final ed., US Dept of Commerce, Bureau of the Census, 1981, publication PHC-80-R3.
[d]Occupation codes for Washington State based on a modified version of that published by US Bureau of the Census, Classified Index of Occupations and Industries, 1960 Census of Population, Washington, DC, USPO, 1960.
[e]Statistically significant, $p < .05$;
[f]Statistically significant, $p < .01$;
NR = not reported.

workers. The analysis was repeated using a *blue collar comparison population consisting of all workers whose occupations were classified in the categories of precision crafts workers, operator, or laborer.* The blue collar analysis was run to control for the known association of many of the outcomes with risk factors such as smoking and/or lifestyle of blue collar workers.

Proportionate Mortality Ratio Analysis

Proportionate mortality ratio analysis based on the underlying cause of death was used to evaluate the mortality patterns of construction workers. The underlying causes of death were coded by state nosologists according to the International Clas-

TABLE II. Index to Tables and Codes Used to Select Construction Occupations for Analysis

Occupation census code	Table number	Occupation title
060 (industry code)	III	Construction industry
553, 563–4	IV	Brickmasons, stonemasons, apprentices
554, 567–69	IV	Carpenters, apprentices
556, 579	IV	Painters, construction and maintenance
557, 585, 587	IV	Plumbers, pipefitters, steamfitters, apprentices
593	IV	Insulation workers
844	IV	Operating engineers
543	IV	Elevator installer and repairers
595	IV	Roofers
597	IV	Structural metal workers
588	IV	Concrete and terrazzo finishers
555, 575–6	IV	Electricians, apprentices
577	IV	Electrical power installers and repairers
869	IV	Construction laborers
565	IV	Tile setters, hard and soft
566	IV	Carpet installers
573	IV	Drywall installers
596	IV	Sheetmetal duct installers
643	IV	Boilermakers
584	IV	Plasterers

sification of Disease, ninth revision [WHO, 1978]. PMRs were calculated using a computer program developed at NIOSH [Dubrow, 1986] that was designed to calculate PMRs for occupations or industries for population-based data. This program calculates proportionate mortality ratios (PMRs) by comparing the proportion of deaths from a specific cause within a specified occupation or industry group with the proportion of deaths due to that cause among all decedents. PMRs were computed after stratification for age (ages 20–64, ages 65+), race (black, white), and gender. PMRs were computed for all ages and for white males who died before age 65, since usual occupation would be reported more accurately before retirement. A PMR above 100 is considered elevated over the average for all occupations. Exact 95% confidence intervals for the true mean observed deaths were calculated by assuming that the observed deaths were distributed as a Poisson random variable. The endpoints of these confidence intervals were divided by the expected deaths to yield 95% confidence intervals (shown in the tables) on the true PMR [Bailar, 1964]. Statistical significance ($p<.05$ for a two-sided test) and 95% two-sided confidence intervals were determined, but should be evaluated in the context of hypothesis generation because multiple comparisons were made [Rothman, 1986].

PMRs are usually computed when data for the population at risk are not available and rates of death or SMRs cannot be calculated. The population at risk for this study includes all persons who ever worked in the construction industry in these states and were at risk of dying January 1, 1984 through December 31, 1986. Because data were not available for the population of construction workers at risk, we evaluated proportionate mortality based on cumulative deaths over a 3-year period. Thus our PMRs indicate whether the proportion of deaths due to a specific cause appears to be high or low for a particular occupation.

RESULTS

The proportionate mortality for the years 1984 through 1986 of construction industry workers and skilled trades is summarized in Tables III–IV. Because the purpose of this analysis was to identify increased mortality, only statistically significant elevated PMRs, PMRs for ischemic heart disease, and the all-cancer PMRs are shown in most tables. However, for a few specific causes of interest, elevated PMRs were listed. PMRs for all causes of death could not be listed due to space limitations.* Because our data did not indicate the circumstances of the traumatic fatality, we excluded most fatality PMRs from our report, except for falls, electrocutions, unintentional poisonings, homicide, suicide, and fatalities classified as usually work-related [WHO, 1978].

PMRs for Construction Industry—All Ages

Elevated PMRs are shown in Table III for 61,682 white men (WM), 9,379 black men (BM), 1,225 white women (WW), and 68 black women (BW), all of whom had been usually employed in the construction industry.

Construction workers experienced mortality deficits for ischemic heart disease and infective and parasitic disease. Exceptions were black male construction workers who had a significant excess of pulmonary tuberculosis (Table III) and black women whose deficit of heart disease was not statistically significant. Statistically significant excesses occurred across a broad panorama of causes for all race-gender groups. They were cancer of the esophagus (WM, BM), cancer of the larynx (WM), cancer of the lung (WM, WW, BW), cancer of connective tissue (WW), cancer of the bladder (WW), nonmalignant respiratory disease (WM, WW), chronic liver disease and cirrhosis (WM), accidental poisonings (WM), falls (WM, BM), usually work-related fatalities (WM), homicide (WM, BM), and a grouped category of alcohol-associated [Anon, 1992a] disorders (WM, BM).

PMRs for Construction Industry—White Males Under Age 65

We evaluated PMRs for white construction industry workers who died before age 65 (Table III). These men experienced a deficit of ischemic heart disease deaths, similar to that observed for men of all ages. Except for a new significant excess for cancer of the nasopharynx (PMR = 158, $p<.05$, 95% CI(100—237), 23 deaths observed), most site-specific cancer PMRs remained about the same magnitude. However, the PMRs for respiratory disease increased substantially, particularly for asbestosis, silicosis, and the overall category of all pneumoconioses. White male construction workers who died before age 65 experienced a more than threefold increased risk for death due to asbestosis (PMR = 393, $p<.01$, 95% CI(196–703), 11 deaths observed) and for silicosis (PMR = 327, $p<.01$, 95% CI(149–620), 9 deaths observed). All PMRs for traumatic fatalities increased slightly.

PMRs by Skilled and Unskilled Trades—White Males

Table IV lists significantly elevated PMRs that occurred among skilled and unskilled trades. For brickmasons elevated risks occurred for cancer of the stomach, larynx, and lung, as well as for mental disorders, nonmalignant respiratory disease, skin disease, homicide, and alcohol-associated disease. Carpenters were observed to

*Data available on request to the authors.

TABLE III. Proportionate Mortality, Construction Industry, 19 U.S. States, 1984–1986[a]

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
WHITE MEN			
All deaths	100	61682	
Cancer of esophagus (150)	115[f]	365	(103–127)
Cancer of larynx (161)	127[f]	201	(108–144)
Cancer of lung (162)	114[f]	5944	(111–116)
Cancer of pleura or peritoneum[g] (1588, 1599, 163)	141	33	(97–198)
Cancer of penis (187)	150	23	(95–226)
Mental disorders (290–319)	121[f]	639	(112–131)
Ischemic heart disease (410–414)	94[f]	15937	(93–95)
Nonmalignant respiratory disease (490–519)	119[f]	4436	(116–122)
Asbestosis (501)	295[f]	24	(189–439)
Chronic liver disease and cirrhosis (571, 5721, 5728)	112[f]	1078	(106–118)
Unintentional poisonings[h] (850–869, 9292)	120[f]	252	(106–136)
Falls (880–888, 9293)	137[f]	507	(126–150)
Fatalities usually work-related (846, 916–921, 923–927)	125[f]	362	(112–138)
Homicide (960–969)	142[f]	720	(132–153)
Alcohol-associated diseases[i] (291, 303, 3050, 3575, 4225, 5353, 7903, 5710–5713, 8600, 8601)	133[f]	861	(124–142)
WHITE MEN WHO DIED UNDER AGE 65			
All cancer (140–208)	98[j]	5357	(96–100)
Cancer of nasopharynx (147)	158[j]	23	(100–237)
Cancer of larynx (161)	136[f]	94	(110–166)
Cancer of lung (162)	110[f]	2401	(106–114)
Cancer of pleura, peritoneum[g] (1588, 1599, 163)	131	12	(68–229)
Cancer of penis and other male genital organs (187)	129	7	(52–266)
Mental disorders (290–319)	131[f]	308	(116–146)
Ischemic heart disease (410–414)	91[f]	4757	(88–93)
Nonmalignant respiratory disease (490–519)	117[f]	889	(109–125)
Chronic obstructive lung disease (490–496)	122[f]	733	(113–131)
Pneumoconioses (500–505)	182[f]	22	(114–275)
Asbestosis (501)	393[f]	11	(196–703)
Silicosis (502)	327[f]	9	(149–620)
Digestive diseases (520–579)	116[f]	1091	(110–122)
Chronic liver disease and cirrhosis (571, 5721, 5728)	118[f]	738	(110–127)
Unintentional poisonings (850–869, 9292)	120[f]	226	(105–136)
Falls (880–88, 9293)	177[f]	254	(156–200)
Fatalities usually work-related (846, 916–921, 923–927)	130[f]	325	(116–145)
Homicide (960–969)	144[f]	690	(134–156)
Alcohol associated diseases[i] (291, 303, 3050, 3575, 4255, 5353, 7903, 5710–13, 8600, 8601)	135[f]	660	(125–145)
BLACK MEN			
All deaths	100	9379	
Pulmonary tuberculosis (002)	160[j]	32	(109–225)
Cancer of esophagus (150)	131[f]	158	(112–153)
Cancer of lung (162)	105	782	(98–112)

(continued)

TABLE III. *(Continued)*

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
BLACK MEN *(continued)*			
Cancer of penis (187)	130	5	(42–304)
Secondary, ill-defined cancer (195–199)	119[f]	194	(103–137)
Ischemic heart disease (410–414)	90[f]	1476	(86–94)
Mental disorders (290–319)	119[j]	191	(103–137)
Falls (880–888, 9293)	174[f]	85	(139–215)
Homicide (960–969)	115[f]	532	(105–125)
Alcohol-associated diseases[i] (291, 303, 3050, 3575, 4225, 5353, 7903, 5710–5713, 8600, 8601)	118[f]	265	(105–134)
WHITE WOMEN			
All deaths	100	1232	
Cancer of esophagus (150)	165	4	(45–423)
Cancer of lung (162)	126[j]	81	(100–157)
Cancer of connective tissue (171)	374[f]	10	(180–688)
Cancer of bladder (188)	248[j]	9	(113–471)
Secondary, ill-defined (195–199)	128	29	(86–184)
Ischemic heart disease (410–414)	84[j]	233	(74–96)
Nonmalignant respiratory disease (490–519)	163[f]	67	(126–207)
Suicide (950–959)	124	24	(79–185)
BLACK WOMEN			
All deaths	100	68	
All cancer (140–208)	130	20	(79–200)
Cancer of lung (162)	272	6	(100–593)
Ischemic heart disease (410–414)	70	8	(30–137)
Nonmalignant respiratory disease (490–519)	183	3	(38–536)
Homicide (960–969)	144	3	(30–421)

[a]Analyses based on occupation-coded death certificate data for 1984–1986 provided to NIOSH by 19 U.S. states for evaluation and follow-up. Occupational coding was supported by NIOSH, National Cancer Institute, and National Center for Health Statistics.

[b]Code of the International Classification of Diseases, 9th rev., 1978, in parentheses.

[c]Proportionate mortality ratio (observed/expected mortality × 100).

[d]Observed.

[e]Exact 95% confidence intervals for the true mean observed deaths were calculated by assuming that the observed deaths were distributed as a Poisson random variable. The endpoints of these confidence intervals were divided by the expected deaths to yield 95% confidence intervals (shown in the table) on the true PMR [Bailar JC, 1964].

[f]$p < 0.01$.

[g]May include mesotheliomas.

[h]May include lead poisoning.

[i]Causes of death attributed by the National Center for Health Statistics to alcohol-induced mortality include alcoholic psychoses, alcohol dependence syndrome, nondependent abuse of alcohol, alcoholic polyneuropathy, alcoholic cardiomyopathy, alcoholic gastritis, chronic liver disease, and cirrhosis specified as alcoholic, excessive blood level of alcohol and accidental poisoning by alcohol, not elsewhere classified. These causes exclude accidents, homicides, and other causes indirectly related to alcohol use [Anon, 1992a].

[j]$p<0.05$.

TABLE IV. Cause-Specific Proportionate Mortality by Construction Occupation, 19 U.S. States, 1984–1986, White Men[a]

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
Brickmasons			
All deaths	100	2,351	
All cancer	108	594	(100–118)
Cancer of stomach (151)	208[f]	32	(142–293)
Cancer of larynx (161)	213[g]	13	(113–365)
Cancer of lung (162)	120[f]	240	(106–137)
Cancer of bone (170)	249	3	(51–727)
Melanoma (skin) (172)	130	11	(65–233)
Cancer of bladder (188)	132	19	(80–207)
Mental disorders (290–319)	187[f]	38	(133–257)
Ischemic heart disease (410–414)	89[f]	590	(83–97)
Nonmalignant respiratory disease (490–519)	133[f]	191	(115–154)
Pneumoconioses (500–505)	264	6	(97–574)
Skin disease (680–709)	273[g]	7	(110–563)
Musculoskeletal disease	165	7	(66–339)
Homicide (960–969)	175[f]	28	(116–252)
Alcohol-associated diseases[h] (219, 303, 3050, 3575, 4255, 5353, 7903, 5710–13, 8600, 8601)	181[f]	44	(132–244)
Carpenters			
All deaths	100		
All cancer	102	3,731	(100–105)
Cancer of lung (162)	116[f]	1,489	(111–121)
Cancer of pleura and peritoneum[i] (1588, 1589, 163)	163	14	(89–274)
Ischemic heart disease (410–414)	94[f]	4,302	(92–97)
Nonmalignant respiratory disease (490–519)	124[f]	1,278	(118–130)
Falls (800–888, 9293)	133[f]	135	(112–158)
Homicide (960–969)	145[f]	151	(123–170)
Alcohol-associated diseases[h] (219, 303, 3050, 3575, 4255, 5353, 7903, 5710–13, 8600, 8601)	126[f]	176	(110–176)
Construction and maintenance painters			
All deaths	100	5,902	
Viral hepatitis B	139[g]	64	(107–178)
All cancer (140–208)	103	1,413	(98–107)
Cancer of larynx (161)	165[g]	25	(107–144)
Cancer of lung (162)	124[f]	615	(114–134)
Cancer of bladder (188)	137[g]	50	(101–180)
Mental disorders (290–319)	182[f]	91	(146–223)
Ischemic heart disease (410–414)	88[f]	1,450	(84–92)
Nonmalignant respiratory disease (490–519)	127[f]	468	(116–139)
Silicosis (502)	449[g]	4	(123–1151)
Diseases of stomach, duodenum (531–537)	151[g]	33	(104–213)
Chronic liver disease and cirrhosis (571, 5721, 5728)	123[g]	109	(101–148)
Falls (880–888, 9293)	149[g]	52	(111–175)
Unintentional poisonings[j] (850–869, 9292)	153[g]	26	(100–225)
Homicide (960–969)	144[f]	58	(110–187)
Alcohol-associated diseases[h] (291, 303, 3050, 3575, 4255, 5353, 7903, 5710–13, 8600, 8601)	175[f]	102	(143–212)

(continued)

TABLE IV. *(Continued)*

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
Plumbers			
All deaths	100	5,214	
All cancer (140–208)	106[g]	1324	(101–111)
Nasal cancer (1600, 1601, 1603–9)	287	2	(35–1037)
Cancer of lung (162)	110[g]	508	(101–120)
Cancer of pleura[i] (163)	327[g]	5	(106–763)
Ischemic heart disease (410–414)	98	1,462	(94–102)
Nonmalignant respiratory disease (490–519)	113[g]	378	(102–125)
Asbestosis (501)	1097[f]	8	(474–2162)
Unintentional poisonings[j] (850–869, 9292)	140	17	(82–225)
Insulation workers			
All deaths	100	267	
All cancer (140–208)	150[f]	101	(122–182)
Cancer of lung (162)	193[f]	51	(157–229)
Cancer of peritoneum[i] (158)	13486[f]	4	(1989–)
Cancer of pleura[i] (163)	2467[f]	2	(298–8913)
Ischemic heart disease (410–414)	67[f]	48	(50–89)
Nonmalignant respiratory disease (490–519)	152[g]	22	(102–202)
Asbestosis (501)	23197[f]	9	(–)
Operating engineers			
All deaths	100	3731	
All cancer (140–208)	104	981	(97–110)
Nasal cancer (1600, 1601, 1603–1609)	271	3	(56–792)
Cancer of lung (162)	120[g]	434	(109–131)
Ischemic heart disease (410–414)	97	1022	(92–102)
Nonmalignant respiratory disease (490–519)	112	255	(99–127)
Fatalities usually work-related (846, 916–921, 923–927)	257[f]	41	(184–348)
Elevator installers and repairers			
All deaths	100	63	
All cancer (140–208)	122	19	(73–190)
Cancer of lung (162)	203[g]	12	(105–355)
Ischemic heart disease (410–414)	40[f]	7	(15–81)
Pneumonia and influenza (480–487)	248	4	(68–635)
Non-malignant respiratory disease (490–519)	189	7	(76–390)
Roofers			
All deaths	100	967	
Mental disorders (290–319)	195[f]	18	(116–308)
Ischemic heart disease (410–414)	74[f]	165	(63–86)
Nonmalignant respiratory disease (490–519)	149[f]	67	(115–189)
Asbestosis (501)	1873[g]	2	(227–6766)
Chronic liver disease and cirrhosis (571, 5721–5728)	168[f]	30	(114–240)
Falls (880–88, 9293)	287[f]	19	(173–499)
Homicide (960–969)	190[f]	36	(133–263)
Alcohol associated diseases[h] (291, 303, 3050, 3575, 4255, 5353, 7903, 5710–13, 8600, 8601)	272[f]	37	(191–374)

(continued)

TABLE IV. *(Continued)*

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
Structural metal workers			
All deaths	100	1064	
All cancer (140–208)	96	245	(85–109)
Cancer of lung (162)	129[f]	122	(107–154)
Ischemic heart disease (410–414)	97	281	(86–109)
Falls (880–88, 9293)	344[f]	21	(213–526)
Fatalities usually work-related (846, 916–921, 923–927)	310[f]	17	(181–497)
Homicide (960–969)	167[g]	16	(105–228)
Concrete/terrazzo finishers			
All deaths	100	516	
Cancer of stomach (151)	179	6	(66–389)
Cancer of bone, cartilage (170)	959[f]	3	(198–2801)
Kidney cancer (189)	303[f]	9	(139–576)
Ischemic heart disease (410–414)	94	130	(79–111)
Electricians			
All deaths	100	6345	
All cancer (140–208)	104[g]	1570	(100–109)
Cancer of lung (162)	114[f]	626	(105–123)
Cancer of peritoneum[i] (158)	225	8	(97–443)
Cancer of pleura (mesothelioma) (163)	331[g]	6	(122–719)
Cancer of penis (187)	250	4	(68–641)
Cancer of scrotum (1877, 1879)	1056[g]	2	(128–3813)
Aplastic anemia (284)	235[g]	8	(101–463)
Ischemic heart disease (410–414)	94[f]	1678	(90–98)
Nonmalignant respiratory disease (490–519)	110[g]	436	(101–119)
Asbestosis (501)	349	3	(72–1019)
Disease of pancreas (577)	178	15	(100–293)
Fatalities usually work-related (846, 916–921, 923–927)	215[f]	55	(162–280)
Electrocutions (925)	653[f]	33	(450–917)
Electrical power installers and repairers			
All deaths	100	788	
All cancer (140–208)	108	200	(94–124)
Cancer of rectum (154)	195	6	(72–425)
Cancer of gall bladder (156)	343	4	(93–878)
Cancer of brain, nervous system (191–192)	172	8	(74–339)
Multiple sclerosis and disease of central nervous system (340–341)	539[g]	3	(111–1575)
Ischemic heart disease (410–414)	96	214	(84–110)
Nonmalignant respiratory disease (490–519)	120	59	(92–115)
Fatalities usually work-related (846, 916–921, 923–927)	626[f]	19	(377–978)
Electrocutions (994)	2720[f]	16	(1555–4417)
Construction laborers			
All deaths	100	9639	
Pulmonary tuberculosis	213[g]	10	(102–392)
All cancers (140–208)	95[g]	2072	(92–99)

(continued)

TABLE IV. *(Continued)*

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
Construction laborers *(continued)*			
Cancer of lip, oral cavity, pharynx (140–149)	130	61	(99–167)
Cancer of lung (162)	113[f]	894	(106–121)
Mental disorders (290–319)	128[f]	108	(105–155)
Ischemic heart disease (410–414)	91[f]	2250	(88–94)
Chronic pulmonary heart disease (416)	164	12	(85–286)
Nonmalignant respiratory disease (490–519)	128[f]	685	(118–137)
Pneumonia, influenza (480–487)	114[g]	276	(101–128)
Asbestosis (501)	250	3	(52–731)
Silicosis (502)	153	2	(18–552)
Chronic liver disease and cirrhosis (571, 5721–5728)	133[f]	211	(116–153)
Sudden death (cause unknown) (798–799)	124[g]	139	(104–147)
Falls (880–888, 9293)	138[f]	84	(110–171)
Homicide (960–969)	175[f]	216	(152–200)
Alchol associated diseases[h] (291, 303, 3050, 3575, 4355, 5353, 7903, 5710–13, 8600, 8601)	163[f]	182	(140–188)
Tile setters			
All deaths	100	184	
All cancer (140–208)	115	54	(86–150)
Cancer of lip, oral, pharynx (140–149)	186	2	(22–672)
Cancer of lung (162)	169[f]	31	(115–240)
Cancer of brain and nervous system (191–192)	221	3	(46–646)
Ischemic heart disease (410–414)	77	39	(55–106)
Nonmalignant respiratory disease (490–519)	133	14	(73–224)
Carpet installers			
All deaths	100	317	
All cancer (140–208)	87	60	(66–112)
Cancer of lip, oral, pharynx (140–149)	191	3	(39–558)
Cancer of lung (162)	132	33	(91–185)
Ischemic heart disease (410–414)	88	64	(69–113)
Nonmalignant respiratory disease (490–519)	161[g]	23	(102–242)
Homicide (960–969)	217[g]	14	(119–364)
Drywall installers			
All deaths	100	355	
All cancer (140–208)	105	77	(83–131)
Cancer of lip, oral, pharynx (140–149)	232	4	(63–595)
Cancer of lung (162)	121	31	(82–171)
Mental disorders (290–319)	256[g]	10	(123–471)
Ischemic heart disease (410–414)	87	66	(68–111)
Alcohol associated diseases[h] (291, 303, 3050, 3575, 4355, 5353, 7903, 5710–13, 8600, 8601)	226[f]	15	(126–372)
Sheetmetal duct installers			
All deaths	100	196	
All cancer (140–208)	109	50	(81–143)
Cancer of larynx (161)	388	2	(47–1400)
Secondary and ill-defined cancer (195–199)	188	6	(69–409)
Diseases of the nervous system and sense organs (320–389)	138	4	(38–353)

(continued)

TABLE IV. ***(Continued)***

Cause of death[b]	PMR[c]	Obs[d]	95% CI[e]
Sheetmetal duct installers *(continued)*			
Ischemic heart disease (410–414)	110	60	(84–141)
Other ischemic heart disease (411–414)	139	31	(94–197)
Diseases of arteries and capillaries (440–448)	188	8	(81–370)
Alcohol associated diseases[h] (291, 303, 3050, 3575, 4255, 5353, 7903, 5710–13, 8600, 8601)	299[g]	6	(110–650)
Boilermakers			
All deaths	100	679	
All cancer (140–208)	106	168	(91–123)
Cancer of larynx (161)	172	3	(36–503)
Acute myeloid leukemia (2050)	259	4	(71–663)
Parkinson's disease (332)	174	4	(48–447)
Ischemic heart disease (410–414)	85[g]	167	(72–98)
Other forms of heart disease (420–429)	119	75	(93–149)
Asbestosis (501)	3238[f]	3	(668–9462)
Plasterers			
All deaths	100	320	
All cancer (140–208)	103	74	(80–129)
Cancer of lip, oral cavity, pharynx (140–9)	206	3	(43–603)
Cancer of larynx (161)	646[g]	5	(210–1507)
Cancer of lung (162)	127	32	(87–180)
Cancer of brain and nervous system (191–192)	181	3	(37–528)
Ischemic heart disease (410–414)	87	79	(69–109)
Chronic liver disease and cirrhosis (571, 5721–8)	189	8	(81–372)

[a]Analyses based on occupation-coded death certificate data for 1984–1986 provided to NIOSH by 19 U.S. states for evaluation and follow-up. Occupational coding was supported by NIOSH, National Cancer Institute, and National Center for Health Statistics.
[b]Code of the International Classification of Diseases, 9th rev., 1978, in parentheses following.
[c]Proportionate mortality ratio (observed/expected proportionate mortality × 100).
[d]Observed.
[e]Exact 95% confidence intervals for the true mean observed deaths were calculated by assuming that the observed deaths were distributed as a Poisson random variable. The endpoints of these confidence intervals were divided by the expected deaths to yield 95% confidence intervals (shown in the table) on the true PMR (Bailar JC, 1964).
[f]$p < 0.01$.
[g]$p < 0.05$.
[h]Causes of death attributed by the National Center for Health Statistics to alcohol-induced mortality include alcoholic psychoses, alcohol dependence syndrome, nondependent abuse of alcohol, alcoholic polyneuropathy, alcoholic cardiomyopathy, alcoholic gastritis, chronic liver disease and cirrhosis specified as alcoholic, excessive blood level of alcohol and accidental poisoning by alcohol, not elsewhere classified. These causes exclude accidents, homicides, and other causes indirectly related to alcohol use [Anon, 1992a].
[i]May include mesotheliomas.
[j]May include lead poisoning.

have significantly elevated PMRs for lung cancer, nonmalignant respiratory disease, falls, homicide, and alcohol-associated disease. Construction and maintenance painters experienced statistically significant elevated PMRs for viral hepatitis B, cancers of the larynx, lung, and bladder, mental disorders, nonmalignant respiratory disease, silicosis, diseases of the stomach and duodenum, chronic liver disease and cirrhosis,

falls, unintentional poisonings, homicide, and alcohol-associated disease. Plumbers were observed to have statistically significant elevated PMRs for all cancer, cancer of the lung and pleura (mesothelioma), nonmalignant respiratory disease, and asbestosis. Insulators had statistically significant elevated PMRs for all cancer, cancer of the lung, peritoneum, and pleura (mesothelioma), nonmalignant respiratory disease, and asbestosis. Table IV also shows that significantly elevated PMRs were observed among operating engineers for lung cancer and injuries usually work-related. Only 63 total deaths were reported for elevator installers and repairers during the study years. Small numbers for cause-specific deaths resulted in elevated PMRs for lung cancer, pneumonia and influenza, and nonmalignant respiratory disease. Only the PMR for lung cancer was statistically significant.

Roofers are reported in Table IV to have significantly elevated PMRs for mental disorders, nonmalignant respiratory disease, asbestosis, chronic liver disease and cirrhosis, falls, homicide, and alcohol-associated diseases. Structural metal workers had elevated PMRs for lung cancer, falls, injuries usually work-related, and homicides. Significantly elevated PMRs were observed among concrete and terrazzo finishers for bone and kidney cancer, although many PMRs were elevated.

Table IV shows significantly elevated PMRs among electricians for all cancer, cancer of the lung, pleura (mesothelioma), and scrotum, aplastic anemia, nonmalignant respiratory disease, injuries usually work-related, and electrocutions. PMRs were elevated for different causes among the much smaller group of electrical power installers and repairers, but only the PMRs for multiple sclerosis, injuries usually work-related, and electrocutions were statistically significant. PMRs among construction laborers were significantly elevated for pulmonary tuberculosis, lung cancer, mental disorders, nonmalignant respiratory disease, pneumonia and influenza, chronic liver disease and cirrhosis, sudden death, falls, homicides, and alcohol-associated disease.

Statistically significant elevated PMRs for cancer of the lung were observed among tile setters; nonmalignant respiratory disease and homicide among carpet installers; mental disorders and alcohol-associated diseases among drywall installers; and elevated but not significant PMRs for cancer of the larynx, nervous system disease, and cardiovascular disease among sheetmetal duct installers, except for alcohol-associated disorders, which were significantly elevated. Table IV shows significantly elevated asbestosis mortality for boilermakers. A significantly elevated PMR was found for cancer of the larynx for plasterers.

Blue Collar Analysis

The results of the analysis using the *blue collar comparison group* were very similar to those reported above. Overall, many PMRs had decreased slightly from those obtained using all workers as a referent group (Table IV), but remained statistically significant. However, six construction trades had PMRs that decreased and became statistically non-significant. They were: cancer of the larynx (PMR = 143) and silicosis (PMR = 293) among construction and maintenance painters; lung cancer (PMR = 109) among brickmasons; lung cancer (PMR = 103) and nonmalignant respiratory disease (PMR = 98) among electricians; lung cancer (PMR = 100) and nonmalignant respiratory disease (PMR = 98) among plumbers; nonmalignant respiratory disease (PMR = 145) among carpet installers; and lung cancer (PMR = 117) and homicide (PMR = 153) among structural metal workers.

Additionally, six construction trades had PMRs that increased and became statistically significant when the blue collar group was used for comparison. They were cancer of the kidney (PMR = 323, $p<.05$) among insulation workers; diseases of the arteries (PMR = 206, $p<.05$) among plasterers; stroke (PMR = 130, $p<.05$), cancer of the thymus (PMR = 1586, $p<.05$), and diseases of the arteries (PMR = 161, $p<.05$) among electrical power installers and repairers; diseases of the pancreas (PMR = 183, $p<.05$) among painters; and unintentional poisoning (PMR = 183, $p<.05$) among drywall installers.

DISCUSSION

Previous studies of male Swedish and British construction industry workers, as well as those in the states of California and Washington, have reported similar patterns of excess mortality from cancer and from respiratory, nervous, and digestive system disease, as has our study. These patterns were observed among white men in this study and for the other race-sex groups to a lesser degree.

The most striking excesses we observed were for respiratory disease related to asbestos and other hazards, the most well documented construction worksite hazard. In our study, the highest PMRs for white male construction workers under 65 are for asbestosis (PMR = 393) and silicosis (PMR = 327), both increased more than three-fold (Table III). Three prior reports [Englund, 1982; Engholm, 1987; Fletcher, 1990] noted that the excess lung cancer that was observed among Swedish construction workers was attributable to occupational exposure to asbestos. This excess persisted even after adjustment for smoking. Although we could not adjust for smoking or alcohol, the present report observed excess lung cancer and mesothelioma mortality among black and white female construction workers, and white males under age 65 at death, and for men employed in many of the skilled trades and for laborers (Tables III–IV). This may suggest that more emphasis should be placed on the control of silica and asbestos-related diseases. Feasible and safe substitutes for silica in abrasive blasting should be identified.

Significant excess mortality was noted for mental disorders for white and black men usually employed as construction workers, for white construction workers under age 65, and for painters, brickmasons, roofers, construction laborers, and drywall installers. Neurologic impairment and neurobehavioral deficits have been reported for workers exposed to persistently elevated levels of organic solvents or to lead in the work environment, particularly construction painters [Baker, 1986, 1988; Fidler, 1987]. These agents may enhance or cause cancer, other chronic disease, and/or mental disorders.

During health hazard evaluations conducted between 1981–1983 by the National Institute for Occupational Safety and Health (NIOSH), elevated ambient asbestos levels were reported for several construction occupation sites involving skilled trades workers. Thse included electrical work, drywalling, insulation, carpentry, and roofing. However, asbestosis PMRs are probably underestimated (using underlying causes of death) on death certificates due to a change in the nosology decision table for occupational lung diseases that was implemented by the National Center for Health Statistics in 1982 [U.S. Health, 1991]. The change, i.e., deletion of the specificity clause has resulted in some occupational lung disease deaths being coded to the more general category of obstructive pulmonary disease. Construction site

workers may be unaware of exposures to asbestos, lead, and noise, and materials specific to particular trades [Englund, 1981; Schneider, 1993].

New findings of cancer and other health outcomes were observed for specific construction trades as follows: brickmasons—bone cancer and melanoma (skin); sheetmetal workers—cardiovascular disease; plumbers—nasal cancer; construction laborers—pulmonary tuberculosis; electricians—scrotal cancer and aplastic anemia; electrical power installers and repairers—rectal cancer and multiple sclerosis; concrete and terrazzo workers—bone and kidney cancer; boilermakers—acute myeloid leukemia; and white women construction workers—cancer of the connective tissue. Although these are new findings for construction workers, most of these causes have been previously linked by epidemiologic or toxicologic study to specific occupational exposures. The following brief summary suggests hypotheses for further investigation in construction workers. Prevention of cancer should become a focus for future research strategies.

Bone cancer, seen for brickmasons and concrete and terrazzo workers, has been linked with radiation exposure [IARC, 1971]. Additionally, osteogenic sarcoma has been produced in rabbits by intravenous administration of beryllium compounds [IARC, 1971]. In Sweden, a fivefold excess of bone sarcomas was reported in communities with air pollution resulting from ferrous metallurgy plants [Lindahl, 1972]. Construction work at nuclear facilities may involve radiation exposures.

Melanoma has been linked with exposure to ultraviolet radiation in sunlight, early exposure in childhood and adolescence being predictive in some studies [Osterlind, 1988]. Paffenbarger found that paid outdoor work before college was associated with increased incidence of melanoma [Paffenbarger, 1978]. Sunlight exposure to construction workers might be evaluated.

Nasal cancer has been linked with nickel refining and chrome pigment manufacturing [Schottenfeld, 1982], but not reported in previous studies of construction plumbers and pipefitters [Kaminski, 1980; Cantor, 1986]. Nickel and chrome exposures could occur in welding, but mortality is not the best measure of nasal cancer occurrence because of its high survival rate.

Although cases of silico-tuberculosis have been reported in sandblasters [Bailey, 1974], excess mortality from pulmonary tuberculosis has been associated recently with gold miners exposed to silica [Steenland, 1995] and it has been linked to lower socioeconomic status and other occupations [MMWR, 1995].

Sir Percival Pott's observation of an unusually high frequency of scrotal (skin) cancer among London chimney sweeps in 1775 was later shown to be caused by contact with coal tar products [Lueke, 1907; Passey, 1922]. A later association was with cutting oils [Cruickshank, 1950]. Both agents were also linked with lung cancer. The potential for skin contact with coal tar products, benzo(a)pyrenes, or ingestion of cutting oils for electricians during construction work might be evaluated and has been implicated for roofers.

Radiologists who practiced before radiation exposure guidelines were implemented have been observed to have excess deaths from aplastic anemia and skin cancer [Matanoski, 1975]. Electricians may have exposures to electro-magnetic fields or radiation, depending on their work setting.

Multiple sclerosis has not been reported previously in connection with occupation, although there have been several reports of astrocytomas in multiple sclerosis

plaques [Reagan, 1973], implying a link with elevated brain cancer previously reported for men in electrical occupations [Thomas, 1986].

An elevated kidney cancer rate, observed in construction concrete and terrazzo workers, was previously reported for coke oven workers [Redmond, 1972] and was linked with exposure to asbestos [Selikoff, 1979] and cigarette smoking. Acute meloid leukemia has been reported in connection with exposure to nonionizing radiation exposure [Savitz, 1987] and with occupational exposure to benzene [McMichael, 1975], but not for a previously studied cohort of boilermakers [Beaumont, 1980].

Cancer of the connective tissue has been associated with dioxin and arsenic exposures, but not construction occupations, and occurs less often in women than in men [Schottenfeld, 1982]. However, dioxin and arsenic have been used in herbicides and may occur on construction sites in treated lumber.

The dangers of construction sites are well known for catastrophic outcomes. High rates for traumatic fatalities that occurred at work for the construction industry have been previously documented [Stout-Wiegand, 1988; Bell, 1990; NIOSH, 1993].

Exposure to various chemicals, dusts, solvents, and other agents with toxic properties has been recently reported for U.S. construction industry worksites [NIOSH, 1988, 1990a,b; Schneider, 1993] and earlier for Swedish construction industry worksites [Englund, 1981]. Construction site workers may be at risk for health problems associated not only with toxic substances used for their own job tasks, but with the "bystander" and "downstream" exposures present in shared work spaces. Construction industry workers are protected from hazardous exposures under the current OSHA permissible exposure limits (PELs). However, unlike PELs for general industry, PELs for the construction industry are currently based on the 1970 Threshold Limit Values (TLV) recommended by the AIHC [Anon, 1992b], many of which exceed NIOSH Recommended Exposure Limits (RELS).

Lifestyle differences in more frequent use of alcohol and tobacco have been reported for construction workers [Harford, 1992], particularly laborers [Mandell, 1992; Burkhart, 1993]. Although it did not explore all differences, our blue collar analysis had adjusted for lifestyle differences-related excess mortality for construction workers. Some PMRs that were significantly elevated for lung cancer were reduced and became nonsignificant; other lung cancer PMRs remained or became significantly elevated. This finding is similar to that of a previous U.S. study [Singleton, 1989]. Singleton studied death certificate data for California and adjusted for lifestyle, using National Health Interview Survey and U.S. Census data to describe the smoking, alcohol, and socioeconomic status of occupations. Singleton [1989] also found excess mortality that persisted even after adjustment. For example, of nine construction occupations that had significant excess lung cancer, five excesses (Standardized Mortality Ratios—SMRs) remained significant after adjustment for lifestyle-related factors.

Our mortality study results may underestimate the magnitude of nonfatal diseases and disorders. Opportunities for morbidity surveillance should be pursued in tandem with obtaining exposure data.

ADVANTAGES AND LIMITATIONS

Analyses of statements of usual occupation and industry on death certificates are advantageous for the construction industry because it is a widely dispersed workforce

for which epidemiologic studies are difficult and sparsely reported, due to the lack of organized records. Additionally, the large number of deaths available for the present analysis made possible the evaluation of mortality risks for rare causes of death among white men usually employed in construction occupations. The large number of deaths also made it possible to evaluate mortality risks for black men and women and white women construction industry workers but not rare causes of death.

The interpretation of the PMRs is limited by misclassification of cause-of-death and usual occupation as reported on death certificates [Rothman, 1986]. The accuracy of occupational information on death certificates compared to interviews has been reported to be ~ 56.8% for construction [Schade, 1988]. Four other studies have reported higher rates of agreement for long-term white workers across all occupations. The studies reported 73.5% [Steenland, 1984], 80% [Peterson, 1974], 75% [Milham, 1976], and 75% [Wegman, 1978] agreement between occupation as listed on the death certificate and as determined by interviewing next-of-kin in case control studies. The degree of misclassification of cause of death varies by disease [Kircher, 1985]. When compared to autopsy findings, death certificate diagnosis was found to be most accurate for cancer, with lesser degrees of accuracy for diagnoses of circulatory, digestive, respiratory diseases, and mental disorders. Both of these misclassification biases would tend to lower risks toward the null. Rather than adjust for the large number of statistical comparisons, we chose to draw on other criteria, such as previously published reports, besides statistical precision in emphasizing associations.

Limitations in the PMR method may also bias risk estimates. For example, when the overall mortality rate of the working population is higher than that for the comparison population, as it has been reported to be for many California construction trades [COMS, 1990], the PMR (as an estimate of the SMR) will be artificially decreased [Decoufle, 1980]. Proportionate cancer mortality analysis has been suggested as one approach to the reduction of artificial changes in the PMR caused by deficits in mortality. However, PMR analysis, when used for population-based studies of workers, has been proposed to be less biased than SMR analysis due to the decreased healthy worker effect, i.e., overall lower death rate among working populations relative to the general population.

CONCLUSIONS

The patterns of excess mortality among white male construction industry workers were similar to those observed in other studies, although we observed them to be occurring before age 65, that may have been employed at death. Significant excess mortality was observed for asbestosis and silicosis in U.S. construction industry workers who died before age 65. Deficits occurred for cardiovascular diseases for all trades except sheet metal workers, although adjustment for blue collar status appeared to elevate cardiovascular mortality for some trades.

New findings were excesses for bone cancer and melanoma in brickmasons, sinonasal cancer in plumbers, cardiovascular disease in sheetmetal workers, pulmonary tuberculosis and silicosis in construction laborers, scrotal cancer and aplastic anemia in electricians, rectal cancer and multiple sclerosis in electrical power installers and repairers, bone and kidney cancer in concrete and terrazzo workers, and acute myeloid leukemia in boilermakers. Sex differences in risk occurred in that women

construction workers experienced excess mortality from cancer of the connective tissue and of the bladder.

This report presents a wealth of information on the mortality patterns of workers across a wide spectrum of construction trades. A national research strategy should be developed to identify the most plausible and worrisome of these associations for nomination for more intensive research. High priority should be given to findings that are of high relative and absolute risk and are consistent between independent studies as well as consistent over time. Sustained mortality surveillance over long periods of time will probably be one of the most effective means of identifying construction industry problems necessitating close attention, in comparison with the inevitable fluctuations in rates due to chance or bias. Further, a national intervention strategy should be begun to develop and implement effective means of intervention among construction worksites.

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