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Mortality Patterns Among Electrical Workers Employed in the U.S. Construction Industry, 1982–1987

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Background *Studies of electrical workers in the utility and manufacturing industries have reported excess site-specific cancer. No previous studies of electrical workers in the construction industry have been conducted.*
Methods *Our study evaluated the mortality patterns of 31,068 U.S. members of the International Brotherhood of Electrical Workers who primarily worked in the construction industry and died 1982–1987.*
Results *Comparison to the U.S. population by using the NIOSH life table showed significantly elevated proportionate mortality for many causes. Excess mortality for leukemia (proportionate mortality ratio (PMR) = 115) and brain tumors (PMR = 136) is similar to reports of electrical workers with occupational exposure to electric and magnetic fields in the electric utility or manufacturing industry. Excess deaths due to melanoma skin cancer (PMR = 123) are consistent with findings of other PCB-exposed workers. A significantly elevated PMR was observed for the diseases caused by asbestos: lung cancer (PMR = 117), asbestosis (PMR = 247), and malignant mesothelioma (PMR = 356) and from fatal injuries, particularly electrocutions (PMR = 1180). The findings of statistically significant excess deaths for prostate cancer (PMR = 107), musculoskeletal disease (PMR = 130), suicide (PMR = 113), and disorders of the blood-forming organs (PMR = 141) were unexpected.*
Conclusion *Results suggest that more detailed investigations of occupational risk factors and evaluation of preventive practices are needed to prevent excess mortality in this hazardous occupation.* Am. J. Ind. Med. 36:630–637, 1999. *Published 1999 Wiley-Liss, Inc.*†

KEY WORDS: electrician; electrocution; mesothelioma; brain tumor; leukemia; magnetic field; blood disorders; injuries; indoor; outdoor

INTRODUCTION

This is the first study of electrical workers who work on residential or industrial construction sites. There are two subgroups of electrical workers in the construction industry: outside work involving high voltage wiring taking place between the community substation and the consumer and indoor work involving wiring of interior circuitry. According to union officials with the International Brotherhood of Electrical Workers (IBEW), construction members tend to stay with either indoor or outdoor work most of their working life, because of the degree of skill required. The IBEW reports 257,000 or 28% are active members in locals that are dominated by construction industry work, and 643,000 are active members in other industries including utility, manufacturing, radio, television, railroad, and others. [Personal communication, Mark Evert, IBEW]. Previous

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studies of electrical workers in the utility and manufacturing industries focused on the effects of occupational exposures to electric and magnetic fields. They have reported findings of excess brain tumors, leukemia, melanoma skin cancer, breast cancer, musculoskeletal disorders, depression, suicide, electrocution, and Alzheimer's disease among electrical workers in the utility or manufacturing industries [Bowman et al., 1992; Casini, 1993; Floderus et al., 1993; London, 1994; Savitz and Loomis, 1995; Savitz et al., 1994; Theriault et al., 1994]. A previous study of U.S. construction workers found excess risks for asbestos-related diseases, including mesothelioma, lung cancer, and asbestosis, as well as other cancers, digestive diseases, poisonings, homicide, and fatal injuries and reported exposures to a wide variety of work site hazards [Robinson et al., 1995].

The construction industry presents unique challenges for occupational health research and prevention because it involves large numbers of relatively small employers, multiemployer work sites, many hazardous exposures, and a highly mobile workforce. In 1990, the Congress of the United States allocated funds for the National Institute for Occupational Safety and Health (NIOSH) to develop a comprehensive prevention program directed at health and safety problems affecting construction workers. One facet of the program was to conduct union-based studies to characterize the cause-specific mortality experience of the construction trades. The purpose of the current study was to identify any excess mortality and potentially hazardous exposures to electrical workers on construction sites as a starting point for prevention efforts.

MATERIALS AND METHODS

The present study was based on the death benefit files maintained by the IBEW. Under the IBEW bylaws, the family of the deceased electrical worker was eligible for the fraternal benefit if he/she had belonged to the IBEW for at least 6 months and had died while an active member or after retirement. Only *electrical workers in construction* are eligible for the fraternal death benefit. The national union administers the death benefit and requires that the local union submit a death certificate as proof of death. The national union also tries to ensure that all deceased members are identified and scans Social Security tapes every few years for its members. In addition to the fraternal benefit, the IBEW has a Pension plan, started in 1928.

Our study was limited to the deaths of 31,068 members whose computerized records were obtainable from the IBEW national office and whose death certificates could be located. All death certificates were coded for the study by an experienced and qualified nosologist according to the Ninth Revision of the International Classification of Diseases (ICD-9) [WHO, 1977]. Members who died outside the United States were excluded from study, due to the unavailability of appropriate death rates (proportions) for analysis and the small numbers of deaths. Only deaths that occurred from January 1, 1982 through December 31, 1987 and deemed eligible by the union for survivor benefits were included.

The records of members who were in arrears on dues and subsequently terminated are not maintained by the union. Thus, terminated electrical workers could not be included in the study. Any electrical worker in arrears on dues is dropped from membership after six months of nonpayment. At that time, the record is purged from the computer file. Because the person–years of terminated members who are at risk are missing from the study population, it would be inappropriate to conduct a cohort analysis of the study population using standardized mortality ratios (SMRs). Thus, the measure of effect chosen was the proportionate mortality ratio (PMR) [Hernberg, 1992].

Statistical analysis was conducted using the NIOSH life table program adapted for proportionate mortality analysis [Steenland et al., 1990; Waxweiler et al., 1983]. The life table program used compared the proportionate mortality of the electrical workers to that expected based on the proportionate mortality of the United States employed population, after stratification of deaths and person–years at risk by potential confounders (age, gender, calendar time). Rates were available for 99 different categories of death. The significance of the results was determined using the Poisson distribution and two-sided, 95% confidence intervals.

Subgroups of electrical workers were formed based on the industrial skill classification of the local union which the member had joined. These data were recorded on the national union records, and are not reported on death certificates. The industrial skill classification and resultant subgroups were not mutually exclusive. Also we found that 5% of members lacked a local union code at death. We substituted the local union at initiation or time of joining for these workers, and excluded any who did not have any local union from the analysis.

RESULTS

Included in the study were 30,686 white males, 114 white females, 266 non-white males, and 2 non-white females whose families were eligible to receive a union death benefit. These electrical workers were either working or retired at death. Cause of death data could not be obtained for less than 0.1% of members known to be deceased. Figure 1 shows the distribution of the number of years in the union for deceased electrical workers. We found that based on union records, over 80% of the deceased electrical workers had over 30 years of employment (membership) as electrical workers.

Table I shows selected PMRs for all electrical workers combined, non-white males, and white females. These

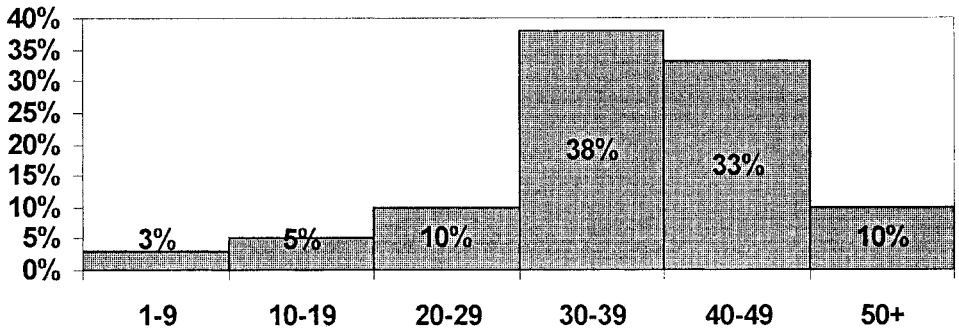

FIGURE 1. Distribution of years in the union for electrical workers in the U.S. construction industry who died 1982–1987.

results indicate that electrical workers have significant proportionate excesses of mortality due to mesothelioma or cancer of the pleura, as well as leukemia and cancer of the lung, skin (melanoma), and prostate. In addition, a statistically significant excess of deaths due to benign or unspecified tumors of the eye, brain, and central nervous system was observed. An evaluation of death certificates revealed these to be mostly brain tumors. Results for non-cancer outcomes indicated excesses for diseases of the blood forming organs, cirrhosis of the liver, asbestosis, and musculoskeletal disease. Mortality from ischemic heart disease was significantly lower than that for the total U.S. population, except among non-white males whose mortality was slightly elevated (PMR = 129).

Results for fatal injuries indicated a considerable excess of mortality among all workers combined and non-white males (Table I). Transportation injuries involving railway and motor vehicles (traffic and nontraffic); water, air, and space transport fatalities; and other injuries were significantly elevated for all workers combined. This latter category (other injuries) includes 137 deaths due to circumstances of being struck by, striking against, or caught between worksite machinery or equipment. There were 127 fatal injuries that were caused by electric current among all workers combined.

Based on information from the death certificates, we found that 115 or 90% of the electrical fatalities among electrical workers occurred at the construction worksite. One hundred nineteen of the 127 electrical fatalities were under the age of 65. PMRs were significantly elevated for all five year age groups between 20 and 64 years. Forty-nine of 119 victims (41%) were less than 35 years of age when they died (Fig. 2).

Using the local union skill classification recorded in the national union records, we identified a subgroup of 12,071 electrical workers who had belonged to local unions and did outside work on construction sites (Table II). The mortality patterns of electrical workers were similar to, or slightly lower than the entire union (Table I), with the exception of the significantly elevated PMR for electrical fatalities (PMR = 1559) based on 80 deaths. A proportionately higher number of electrical deaths occurred during outside work.

In contrast, among 18,171 electrical workers who belonged to locals classified as doing indoor work, the PMR for electrical fatalities was decreased but was still very high, (PMR = 934) based on 73 deaths (Table III). Mortality due to other causes was slightly higher among indoor electrical workers for most site-specific cancers, in particular, brain tumors (PMR = 163). PMRs for all fatal injuries, and injuries from work site machinery, were slightly decreased; and transportation-caused injuries were increased slightly, compared to those of all electrical workers.

DISCUSSION

Our results showed a small but statistically significant excess of brain tumor deaths, based on 118 benign or unspecified tumors of the eye, brain and central nervous system. This is consistent with earlier studies of electricians and with a meta-analysis of brain cancer and occupational exposure to EMF that reported an overall small increase in risk of 10–20% [Kheifets, 1995]. Published epidemiologic studies of electricians have reported elevated risk for brain cancer and tumors of the central nervous system [Theriault et al., 1994; Milham, 1997; Thomas, 1986; Lin, 1985; Preston-Martin et al., 1989].

Our data indicated a significant excess of leukemia among electrical workers in construction. This estimate is consistent with previous studies of workers exposed to electric and magnetic fields that are based on job title or occupation [London, 1994; Milham, 1997; Loomis and Savitz, 1990; Loomis and Savitz, 1991]. Although excess leukemia mortality has been a persistent finding of studies of electricians and electrical workers, a recent meta-analysis [Kheifets et al., 1997] indicated a weaker association with leukemia than that observed for brain tumors [Kheifets et al., 1995]. Alternative explanations for the excess leukemia mortality has been provided by hazard surveillance and other studies. Data from the National Occupational Hazard Survey, which obtained data about the place of work for

TABLE I. Deaths, PMRs, and Confidence Intervals for All Electrical Workers, 1982–87

Cause of death (ICD-9)	Observed number of deaths	Proportionate mortality ratio (PMR)	95% confidence interval
All electrical workers			
All causes (000-999)	31,068	100	99–101
All cancer (140-208)	8,154	110 **	107–112
Cancer of the lung (162)	2,977	117 **	112–121
Cancer of pleura (mesothelioma) (163)	19	356 **	214–555
Cancer of skin (melanoma) (172)	119	123 *	102–147
Cancer of prostate (185)	870	107 *	100–114
Cancer of other and unspecified sites (190-199)	638	120 *	111–130
Leukemia (204-208)	312	115 *	102–128
Benign or unspecified neoplasms of eye, brain, central nervous system (210-239)	118	136 **	112–163
Other diseases of the blood forming organs (288-289, 17-21)	51	141 *	105–186
Ischemic heart disease (410-414)	9,993	97 **	95–99
Asbestosis (501)	13	247 **	131–422
Emphysema (492)	350	108	97–120
Other respiratory diseases (470-478, 494-519)	1,370	98	93–103
Cirrhosis of the liver (571)	512	111 *	102–121
Musculoskeletal system diseases (710-739)	70	130 *	101–165
Arthritis and spondylitis (710-725)	34	140	97–196
All fatal injuries (800-949)	1,192	117 *	110–124
Rail, water, air transportation (800-807, 830-845)	60	138 *	105–177
Machine injuries, struck, caught, explosion, cut, radiation, heat (914, 921, 923-924, 926-928)	138	166 *	139–196
Electrocutions (925)	127	1,180 **	984–1,404
Suicide (950–959)	505	113 *	104–124
Non-white males			
All causes (00-999)	266	100	88–113
All cancer (140-208)	59	104	79–134
Cancer of lung (162)	21	110	68–169
Cancer of prostate (185)	9	132	60–251
Leukemia (204-208)	2	130	16–468
Benign or unspecified neoplasms of eye, brain, central nervous system (210-239)	3	475	98–1389
Ischemic heart disease (410-414)	54	129	97–168
Other heart disease (420-423, 425-28, 429.2-424.9)	19	79	48–124
Pneumoconiosis (470-478, 494-519)	11	166	83–298
Musculoskeletal system disease (710-739)	2	358	43–1291
All fatal injuries (800-949)	38	183 **	129–251
Transportation injuries (800-848)	19	185 **	111–289
Females (White)			
All causes (000-999)	114	100	88–112
All cancer (140-208)	27	109	72–158
Cancer of intestine, except rectum (152, 153)	7	223	89–458
Cancer of breast (174)	6	195	24–704
Leukemia (204-208)	2	195	24–704
Mental disorders, not alcoholism (290-302)	5	601 **	195–140
Ischemic heart disease (410-414)	19	62 **	37–96
All fatal injuries (800-949)	6	129	47–280

* indicates $P < .05$, ** indicates $P < .01$.

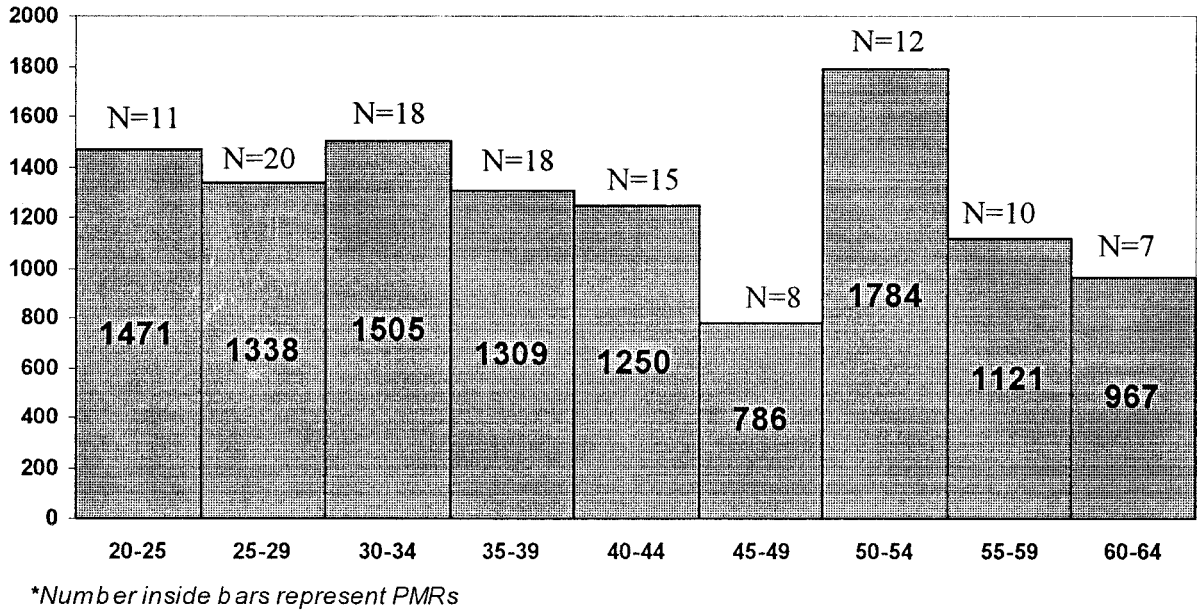

FIGURE 2. Age distribution of electrocuted electrical workers in the U.S. construction industry who died 1982–1987.

TABLE II. PMRs and Confidence Intervals for All Electrical Workers, 1982–87, From Locals Classified as Outdoor

Cause of death (ICD-9)	Observed number of deaths	Proportionate mortality ratio (PMR)	95% confidence interval
PMRs			
All causes (000-999)	12,071	100	98–102
All cancer (140-208)	3,227	111**	107–115
Cancer of the lung (162)	1,246	124**	117–131
Cancer of pleura (mesothelioma) (163)	5	239**	77–559
Cancer of skin (melanoma) (172)	119	123*	102–147
Cancer of other and unspecified sites, (190–199)	240	117**	103–133
Benign or unspecified neoplasms of eye, brain, central nervous system (210-239)	43	127**	92–72
Other diseases of the blood forming organs (288-289, 17-21)	28	202*	134–292
Ischemic heart disease (410-414)	3,414	96**	92–99
Emphysema (492)	161	130**	110–151
Asbestosis (501)	5	247	80–576
Cirrhosis of the liver (571)	218	115*	101–132
All fatal injuries (800-949)	556	125**	115–136
Machine injuries, struck, caught, explosion, cut, radiation, heat (914, 921, 923-924, 926-928)	65	184**	142–235
Electrocutions (925)	80	1559**	1235–1940
Suicide (950-959)	221	114	99–130

*indicates $P < .05$, **indicates $P < .01$.

3,261 electricians and apprentices who worked in the construction industry, reported potential exposure to many hazards, including benzene and 1,3-butadiene [NIOSH 1988, 1990a,b; Sieber et al., 1991]. London reported conducting a questionnaire survey that found that frequency of exposure to chlorinated hydrocarbons was 100% for electricians and apprentices [London, 1994].

Electrical workers on construction sites had excess deaths due to fatal injuries, particularly electrocutions. The excess occurred in young and old workers. Forty-one percent of electrical workers who died by electrocution were less than 35 years of age when they died (Fig. 2). The risk was also high among electrical workers in locals involved in outside work (Table II). Other studies have

TABLE III. PMRs and Confidence Intervals for All Electrical Workers, 1982–87, from Locals Classified as Indoor

Cause of death (ICD-9)	Observed number of deaths	Proportionate mortality ratio (PMR)	95% confidence interval
PMRs			
All causes (000-999)	18,171	100	98–101
All cancer (140-208)	4,908	112 **	109–115
Cancer of the lung (162)	1,851	122 **	117–128
Cancer of pleura (mesothelioma) (163)	14	437 **	239–734
Cancer of skin (melanoma) (172)	81	134 *	107–167
Cancer of other and unspecified sites, minor (190-199)	387	124 **	113–138
Benign or unspecified neoplasms of eye, brain, central nervous system (210-239)	41	163 **	117–221
Ischemic heart disease (410-414)	5,092	95 **	92–98
Asbestosis (501)	11	361 **	180–647
Cirrhosis of the liver (571)	350	120 *	108–133
All fatal injuries (800-949)	768	114 **	106–122
Rail, water, air transportation (800-807, 830-845)	45	146 *	106–122
Machine Injuries, struck, caught, explosion, cut, radiation, heat (914, 921, 923-924, 926-928)	75	139 **	109–174
Electrocutions (925)	73	934 **	732–174

*indicates $P < .05$, **indicates $P < .01$.

reported a higher percent electrocutions in general for younger workers who died at work compared to older workers [Ore and Casini, 1996; Jenkins et al., 1993], but only one study has reported on the electrical fatalities among construction electrical workers [Ore and Casini, 1996].

In addition to observing excess proportionate risk within all age strata (Fig. 2), our study observed significantly elevated PMRs for all 5 year membership strata between 5 and 35 years of union membership. Ore and Casini reported that electrical fatalities in general have been decreasing over the last decade, but are still elevated fourfold [Ore and Casini, 1996]. It is important to find out if the rate of electrical fatality among the electrical workers on construction sites also has been decreasing. The most striking excess, after electrocutions, was of respiratory diseases (including cancers) related to asbestos exposure, a well-documented hazard on construction sites [Sullivan et al., 1995]. The excess risk for mesothelioma clearly indicates exposures to asbestos. When examined by years of exposure, the PMR was significant only after 30 or more years, a typical latency period for asbestos-related mesothelioma. In addition to mesothelioma, electricians experienced a significant excess of asbestosis mortality (PMR = 247). Electricians may receive substantial asbestos exposure, especially while performing building renovation [Hodgson et al., 1988]. Asbestos-related disease and cancer mortality was higher among workers in locals involved in indoor work (Table III).

Construction site electrical workers experienced a significant excess of skin cancer that was due entirely to malignant melanoma (PMR = 123, based on 119 observed deaths) (Table I). When PMRs were evaluated by years of membership, the less than 20 year stratum exhibited the highest significant risk, PMR = 153. Previous studies have associated melanoma with potential exposure to polychlorinated biphenyls (PCBs), that are used in electrical transformers [Rockey et al., 1994; Loomis et al., 1997; Sinks et al., 1992]. Other studies have reported excess melanoma associated with exposures to hydrocarbon solvents, especially formaldehyde, used in insulating materials, wiring, and soldering.

Our data showed a significant excess of prostate cancer. As in the U.S. population [American Cancer Society, 1997], risk was higher for non-white male electrical workers (PMR = 132). Our results confirm previous reports which found electrical power workers at moderate risk of prostate cancer in a population-based case–control study of cancer and occupation in Montreal [Aronson et al., 1996], and by a study of electrical utility workers in Canada and France [Theriault et al., 1994]. In other studies, cadmium exposure was found to be associated with increased prostate cancer incidence [Checkoway et al., 1987]. Electrical workers on construction sites may be exposed to lead and cadmium present in welding fumes.

Our data showed a modest excess of lung cancer (Table I) consistent with the moderately elevated risk found for all electrical workers in published population-based studies [COMS, 1987, Zahm et al., 1989]. The lung cancer PMR was significantly elevated for the less than 20, 20–30, and 30+ years of union membership, typical latency periods for asbestos related lung cancer. Recent data obtained from a large national survey [Brackbill et al., 1988] showed that

prevalence of cigarette smoking among electricians and electrical power installers and repairers was 44% during the years 1978–1980. Cigarette smoking may explain part of the lung cancer excess, since it is well known that risk is multiplicative with concurrent asbestos exposure. Although, most of the previous studies of electrical workers have not reported excesses, one study showed that pulsed electromagnetic fields were strongly associated with lung cancer in Quebec [Armstrong et al., 1994], and the effect could not be explained because of confounding by smoking or other exposures.

Mortality due to diseases of the blood forming organs was significantly elevated (PMR = 141, 51 deaths observed, $P < .05$) (Table I). Most of the deaths were due to white blood cell disorders (ICD 288-289). A recent study reported an exposure–response relationship for benzene and decreased white blood cell count [Ward et al., 1996].

Our findings, when taken with the findings of others, suggest the need for intervention activities directed at the prevention of lung cancer and other respiratory diseases. Many of the excesses are consistent with an occupational etiology. This suggests that further investigations of the unexplained and unexpected excess of mortality via case–control studies, to evaluate specific exposures and work practices among indoor vs. outdoor electrical workers, are needed. Preventive practices need to be reviewed and targeted to meet the needs of this hazardous occupation. The considerable excess mortality observed suggests that mortality patterns need to be reevaluated when death data for the late 1990's become available to determine whether electrical workers continue to experience the excess mortality noted in this study. This occupation was projected to increase by 29% between 1990–2005 [U.S. Census, 1992].

The dangers of work in the construction industry are well known for their catastrophic outcomes. Electrical workers experienced significantly increased mortality for fatalities associated with transportation and with work site machinery. High rates for traumatic fatalities that occurred at work in the construction industry have been previously documented [Jenkins et al., 1993; Bell et al., 1990; Stout-Wiegand, 1988].

Limitations of PMR studies have been widely discussed. They include potential inaccuracies in cause-of-death as mentioned in the death certificates, lack of data on occupational exposure, and the loss of short-term members from the study. These are common limitations of most PMR studies. In our study, lack of data on individuals on indoor or outdoor work may have lead to exposure misclassification, resulting in decreased PMRs.

CONCLUSION

Our study of construction site electrical workers found a striking excess of risk for electrocution at work; modest excesses for brain tumors, leukemia, melanoma skin cancer, prostate cancer, and asbestos-related illnesses—lung cancer, mesothelioma, and asbestosis; and unexpected moderate excesses of suicide, musculoskeletal disease, prostate cancer, and disorders of the blood-forming organs. Many of the excesses suggest or are consistent with an occupational etiology. Further investigations of the indoor vs. outdoor work, and unexplained excess mortality, may be warranted via case–control studies that would evaluate specific exposures and work practices. Preventive measures may need to be reviewed and better targeted for this hazardous occupation.

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REFERENCES

American Cancer Society. 1997. Cancer facts and figures. Atlanta, Georgia.

Armstrong B, Theriault G, Guenel P, Deadman J, Goldberg M, Heroux P. 1994. Association between exposure to pulsed electromagnetic fields and cancer in electric utility workers in Quebec, Canada, and France. Amer J Epidemiol 140:805–820.

Aronson KJ, Siemiatycki J, Dewar R, Gerin M. 1996. Occupational risk factors for prostate cancer: results from a case–control study in Montreal, Quebec, Canada. Amer J Epidemiol 143:363–373.

Bell CA, Stout NA, Bender TR, Conroy C, Crouse W, Myers JR. 1990. Fatal occupational injuries in the US 1980 through 1985. JAMA 263:3047–3050.

Bowman JD, Sobel E, London SJ, Thomas DC, Garabrant DH, Pearce N, Peters JM. 1992. Electric and magnetic field exposure, chemical exposure and leukemia risk in ''electrical'' occupations. The EPRI Report, TR-101723, University of Southern California, Los Angeles, California.

Brackbill R, Frazier T, Schilling S. 1988. Smoking characteristics of US workers 1978–1980. Am J Ind Med 13:5–41.

Casini VJ. 1993. Occupational electrocutions. Professional Safety: 34–9, 1993.

Checkoway H, DiFerdinando G, Hulka B. 1987. Medical, lifestyle, and occupational risk factors for prostate cancer. Prostate 10: 79–88.

COMS—California occupational mortality 1979–1981: Sacramento, 1987.

Floderus B, Persson T, Stenlund C, Wennberg A, Ost A, Knave B. 1993. Occupational exposure to electromagnetic fields in relation to leukemia and brain tumors: a case control study in Sweden. Cancer Causes Control 4:465–476.

Hernberg S. 1992. Introduction to occupational epidemiology. Chelsea: Lewis Publishers. Michigan.

Hodgson MJ, Parkinson DK, Sabo S, Owens G, Feist JH. 1988. Asbestosis among electricians. J Occup Med 30:638–640.

Jenkins EL, Kisner SM, Fosbroke DE, Layne L, Stout NA, Castillo DN, Cutlip PM, Cianfrocco R. 1993. Fatal injuries to workers in the United States, 1980–1989: A decade of surveillance: national profile. Washington, DC: US Government Printing Office. DHHS (NIOSH) Publication no. 93–108.

Kheifets LI, Afifi A, Buffler P, Zhang ZW. 1995. Occupational electric and magnetic field exposure: a meta-analysis. J Occup Environ Med 37:1327–1334.

Kheifets LI, Afifi A, Buffler PA, Zhang ZW, Matkin CC. 1997. Occupational electric and magnetic field exposure and leukemia, a meta-analysis. J Occ Environ Med 39:1074–1091.

Lin RS, Dischinger PC, Conde J, Farrell KP. 1985. Occupational exposure to electromagnetic fields and the occurrence of brain tumors. J Occup Med 27(6):413–419.

London SJ, Bowman JD, Sobel E, Thomas DC, Garabrant DH, Pearce N, Bernstein L, Peters JM. 1994. Exposure to magnetic fields among electrical workers in relation to leukemia risk in Los Angeles County. Am J Ind Med 26:47–60.

Loomis D, Browning SR, Schneck AP, Gregory E, Savitz D. 1997. Cancer mortality among electric utility workers exposed to polychlorinated biphenyls. Occup Environ Med 54:720–728.

Loomis D, Savitz DA. 1990. Mortality from brain cancer and leukemia among electrical workers. Brit J Ind Med 47:633–638.

Loomis D, Savitz DA. 1991. Occupation and leukemia mortality among men in 16 states: 1985–1987. Am J Ind Med 19:509–521.

Milham SJ. Occupational mortality in Washington state 1950–1989. NIOSH Pub No. 96-113, 1997.

NIOSH. 1988, 1990 a,b. National occupational exposure survey. DHHS (NIOSH) Publication No. 88-106, 89-102, 89-103. Washington, DC: US Department of Health and Human Services.

Ore T, Casini V. 1996. Electrical fatalities among US construction workers. J Occup Environ Med 38(6):587–592.

Preston-Martin S, Mack W, Henderson BE. 1989. Risk factors for gliomas and mengiomas in males in Los Angeles county. Cancer Res 49:6137–9143.

Robinson CF, Stern F, Venable H, Petersen M, Frazier T, Burnett CA, Lalich N, Sestito J, Fingerhut M, Halperin W. 1995. The assessment of mortality in the construction industry in the United States 1984–86. Am J Ind Med 28:49–70.

Rockey PF, Trieff N, Wagner RF, Tyring SK. 1994. Nonsunlight risk factors for malignant melanoma part I: chemical agents, physical conditions, and occupation. Int J of Dermato 33(6):398–406.

Savitz DA, Boyle CA, Holmgreen P. 1994. Prevalence of depression in electrical workers. Am J Ind Med 25:165–176.

Savitz D, Loomis DP. 1995. Magnetic field exposure in relation to leukemia and brain cancer mortality among electric utility workers. Am J Epidemiol 141:123–134.

Sieber WK, Sundin DS, Frazier TM, Robinson CF. 1991. Development, use, and availability of a job exposure matrix based on National Occupational Hazard Survey data. Am J Ind Med 20:163–174.

Sinks T, Steele G, Smith AB, Watkins K, Shulte RA. 1992. Mortality among workers exposed to polychlorinated biphenyls. Am J Epidemiol 136:389–398.

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(11):1091–1098.

Stout-Wiegand N. 1988. Fatal occupational injuries in the U.S. in 1980–84: results of the first national census of traumatic occupational fatalities. Scand J Work Environ Health (Suppl 1):90–92.

Sullivan PA, Bang KM, Hearl FJ, Wagner GR. 1995. Respiratory disease risks in the construction industry. Occ Med: State of the Art Reviews 10(2):313–334.

Theriault G, Goldberg M, Miller AB, Armstrong B, Guenel P, Deadman J, Imbernon E, To T, Chevalier A, Cyr D, Wall C. 1994. Cancer risks associated with occupational exposure to magnetic fields among electric utility workers in Ontario and Quebec, Canada, and France: 1970–1989, Am J Epidemiol 139(6):550–572.

Thomas T, Waxweiler RJ. 1986. Brain tumors and occupational risk factor. A review. Scand J Work Environ Health 12:1–15.

US Census. 1992. Bureau of Statistical Abstract of the United States. Washington, DC: US Government Printing Office.

WHO International Classification of Diseases. Ninth Revision. Geneva. World Health Organization, 1977.

Ward E, Hornung R, Morris J, Rinsky R, Wild D, Halperin W, Gutherie W. 1996. Risk of low red or white blood cell count related to estimated benzene exposure in a rubber worker cohort (1940–1975). Am J Ind Med 29:247–257.

Waxweiler RJ, Beaumont JJ, Henry JA, Brown DP, Robinson CF, Ness GO, Wagoner JK, Lemen RA. 1983. A modified life-table analysis system for cohort studies. J Occup Med 25(2):115–124.

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