Human and Ecological Risk Assessment: An International Journal
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/bher20

Work-Related Fatal-Injury Risk of Construction Workers by Occupation and Cause of Death

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Published online: 03 Jun 2010.

Human and Ecological Risk Assessment: Vol. 4, No. 6, pp. 1371-1390 (1998)

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ABSTRACT

To assess cause- and occupation-specific risks of work-related fatal injuries among U.S. construction workers, the National Traumatic Occupational Fatalities (NTOF) surveillance system and Current Population Survey were used to obtain injury and employment data for the years 1990 through 1994. Risks were assessed by both rate and working lifetime risk. The occupation found to have the highest fatal-injury rate in construction was electrical-power installers and repairers (96.6 deaths/100,000 workers), followed by structural-metal workers (86.4) and operating engineers (41.0). The occupation found to have the largest numbers of fatalities was construction laborers (1133 deaths), followed by carpenters (408), and construction supervisors (392). The leading causes of death varied by occupation. Construction in general has experienced a decline in fatal-injury rates over the years; however, this decline did not occur equally across occupations and causes of death. The presentation of working lifetime injury risks provides a measure of risk for occupational injuries that can be compared with occupational illness risk assessments. This study is the first to provide a comprehensive national profile of work-related fatal-injury risks among United States construction workers by occupation and cause of death. The results will be useful in focusing research and prevention efforts on specific hazards in high-risk construction occupations.

Key Words: occupational, NTOF, lifetime risk

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INTRODUCTION

Construction remains one of the largest and most dangerous industries in the United States; approximately 930 construction workers were killed by work-related injury annually from 1990 to 1994. However, little information exists on fatality rates risk by occupation within the industry, probably due to the difficulties in assembling data on both fatalities and populations at risk in an industry characterized by a high proportion of small companies and by large turnover in the work force (Dong *et al.*, 1995). The purpose of this paper is to present findings on fatality risk by occupation and cause of death within the construction industry. These findings support the general research requirement, as identified in the traumatic injuries chapter of the National Occupational Research agenda (NORA) document (NIOSH, 1996), for increased work-sector-specific information to drive intervention and prevention strategies. Findings on occupation and cause of death in construction can clearly be used to drive targeted prevention programs within this industry, one of four industries identified in the NORA document as having fatality rates "notably and consistently higher" than all other industries.

There have been three studies which provided limited information on occupational-fatality risks for selected occupations or occupation groups in the United States' construction industry. In a study that used death certificates from 19 states (Robinson *et al.*, 1995), proportionate mortality ratios (PMRs) were calculated for falls, homicide, unintentional poisonings, and fatalities—usually work-related—for selected occupations. A California occupational mortality study (CDHS, 1987) calculated standard mortality ratios (SMRs) by cause of death for selected occupations or occupation groups in California during 1979 to 1981. A study of Census of Fatal Occupational Injury (CFOI) data from 1992 to 1993 reported work-related fatality rates for selected occupations or occupational groups within the construction industry (Pollack *et al.*, 1996). These three studies used only three or four broad categories to describe various injuries, and, consequently, information on more specific causes of death was not provided. Since mortality was only reported for a limited number of occupations and occupational groups, it is possible that some occupations with high risk of fatal injury were missed. It is also possible that high-risk occupations were grouped with low-risk occupations.

The National Traumatic Occupational Fatalities (NTOF) surveillance system, implemented by the National Institute for Occupational Safety and Health (NIOSH), is a census of death certificates for occupational traumatic fatalities in the United States (Jenkins *et al.*, 1993). Prior to 1990, a 1987 computer algorithm had been used on NTOF data to code information on decedents' usual occupation and industry. The 1987 algorithm produced codes that were accurate at the division, or aggregate level (Castillo and Jenkins, 1994). Beginning in 1990, NTOF data were manually coded for detailed industry and occupation using the Bureau of the Census (BOC) classification system (BOC, 1982; BOC, 1992; Fosbroke, Kisner, and Myers, 1997). This improvement in coding detail makes it possible to assess injury risks by detailed occupation within the construction industry. The current study was conducted using 1990–1994 NTOF data and the Bureau of Labor Statistics' (BLS) Current Population Survey (CPS) data to assess the work-related fatality risk of specific construction occupations and to identify cause- and occupation-specific fatality patterns and the trends of such fatalities over the study period.

MATERIALS AND METHODS

The data source used to define occupational fatalities was NTOF data for the calendar years from 1990 to 1994. The NTOF data were collected from all 52 Vital Statistics reporting agencies in the United States. Methods, strengths, and limitations of the NTOF have been well documented elsewhere (Stout, 1988; Jenkins *et al*., 1993). The inclusion criteria for NTOF are: (1) death resulting from an external cause of injury (E-codes, 800–999) according to the International Classification of Disease, Ninth Revision (ICD-9) (WHO, 1977); (2) victim's age at least 16 years; and (3) a positive response to the death certificate's "Injury at Work?" item.

Employment data were obtained from the Current Population Survey (CPS), a household survey conducted by the Bureau of the Census (BOC) for the Bureau of Labor Statistics (BLS). Data were drawn from the monthly employment files maintained in electronic format by the BLS. Monthly estimates were summed over the year and then divided by 12. Zero estimates were considered valid estimates from the survey, therefore, even when an occupation did not occur in one or more months, the yearly sum was divided by 12. The annual employment estimates were based on workers' primary industry and occupation. Since these estimates do not account for hours worked, a person whose primary job is part-time is treated equally with a person who works full-time at their primary job. Additional information about the Current Population Survey can be found in *Employment and Earnings*, which is published monthly by the BLS.

Information on occupation and industry was coded according to the BOC classification systems. Data for 1990 and 1991 were coded according to the 1980 BOC classification system (BOC, 1982) and data for 1992 through 1994 were coded according to the 1990 BOC classification system (BOC, 1992). The 1980 BOC classification of occupation was converted to the 1990 BOC classification; for the current study results are presented using the 1990 BOC classification of occupation. The injury and employment data included in this study are for persons whose industry was coded as construction (BOC industry code = 60). Results are presented for the civilian work force only, because denominator data are not available for military personnel.

Annual fatality rates are presented as the number of deaths per 100,000 construction workers. Rates were calculated by gender, race, age-group, and cause of death. Occupation rates were calculated for those occupations that had ten or more deaths during the 5 years, while cause- and occupation-specific rates were calculated for those occupations that had 150 or more deaths during the 5 years. Confidence intervals (95% CI) for rates were calculated based on the standard errors of the employment estimates using the approximations and adjustments published in the *Employment and Earnings* (BLS, 1997). For each fatal-injury rate, the upper and lower bounds were calculated for the estimated number of employees used in the rate calculation. Then these upper and lower bounds were used to calculate rates above and below the initial fatal-injury rate.

Lifetime risk was calculated by using an equation proposed by the Occupational Safety and Health Administration (OSHA, 1995): WLTR = $(1 - (1 - R)^y) \times 1000$ where: WLTR = working lifetime risk; R = probability of a worker having a work-related fatal injury in a given year (*e.g.*, average annual fatal-injury rate); y = years of exposure to work-related injury; $(1 - R)^y$ = probability of surviving 'y' years without a work-related fatal injury ("y" set at 45 years); $1 - (1 - R)^y$ = probability of having a work-related fatal injury over 'y' years of employment. The variable WLTR is expressed as the number of deaths per 1000 workers over a 45-year working lifetime.

RESULTS

A total of 4661 work-related injury deaths were identified in the construction industry in the United States in 1990–1994, yielding an average annual rate of 12.7 deaths / 100,000 construction workers. Table 1 presents the number of deaths and rates by age group. Rates were similar by age group until 44 years of age, increased slightly through age 55, then increased rapidly.

Within the construction industry, there were 38 occupations identified as having ten or more deaths during the 5 years, and among these, 22 had a rate higher than the average rate of 12.7 / 100,000 construction workers. Table 2 presents fatal-injury rates by occupation and year, and average annual rates by occupation for the 38 occupations that had ten or more deaths during the 5 years. Electrical power installers and repairers had the highest rate of 96.6, over seven times the average rate of 12.7; followed by structural metal workers (86.4); operating engineers (41.0); drillers, earth (34.8); and supervisors—painters, paperhangers, and plasterers (34.5). The largest number of injury deaths occurred to construction laborers (1,133 deaths), followed by carpenters (408 deaths), construction supervisors, n.e.c. (392 deaths), operating engineers (309 deaths), and electricians (261 deaths).

Overall, the number of fatal work-related injuries declined by 15%, from 1,077 deaths in 1990 to 920 deaths in 1994. The fatal-injury rates decreased by 12%, from 13.9 in 1990 to 12.3 in 1994. Among those occupations that had 150 deaths or more during the 5 years (1990 to 1994), truck drivers; operating engineers; construction supervisors; construction managers and administrators, n.e.c.; and electricians experienced a rate decrease greater than 12% over the 5 years. Construction laborers, the occupation that had the largest number of deaths in construction, experienced an 11% decrease in rate over the years. There was little change in the fatal-injury rate of the painter; carpenter; and construction trades, n.e.c. occupations. Rates for other occupations

Table 1. Work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994 by age-group.[a]

Age groups	Employees[b]	Deaths[c]	Rates[d]	95% CI[e]
16–19	1,080,794	97	9.0	8.2–9.8
20–24	3,763,658	428	11.4	10.6–12.3
25–29	5,280,123	627	11.9	11.2–12.7
30–34	6,379,550	693	10.9	10.3–11.5
35–39	5,733,686	666	11.6	10.9–12.4
40–44	4,602,280	534	11.7	10.8–12.5
45–49	3,303,197	457	13.8	12.8–15.1
50–54	2,661,078	369	13.9	12.7–15.3
55–59	2,018,620	317	15.7	14.2–17.5
60–64	1,195,374	233	19.5	17.2–22.6
65–69	429,425	110	25.6	20.9–33.2
70–74	184,906	75	40.6	30.1–62.1
75–79	52,302	36	68.8	41.7–196.6
80+	20,141	17	84.4	42.6–4548

[a] Two death certificates had unknown age.

[b] Employees: estimated number of employees for 1990 through 1994 from the Current Population Survey (CPS) microdata maintained by the Bureau of Labor Statistics.

[c] Deaths: Number of occupational injury deaths for 1990 through 1994 from the National Traumatic Occupational Fatalities Surveillance system maintained by the National Institute for Occupational Safety and Health.

[d] Rate: Number of occupational fatal injuries per 100,000 workers.

[e] Approximate 95% Confidence intervals are based on the standard errors for the employment estimates in the CPS as published in the *Employment and Earnings* (BLS, 1997).

(*e.g.*, structural metal workers) and for occupations that had fewer than 150 deaths fluctuated widely during the study period.

Table 3 presents cause-specific rates by year in construction. The four leading causes of death (falls, motor-vehicle incidents, electrocutions, and machine-incidents) account for two-thirds of the fatal injuries in construction. Though there was a general decline in the annual rates for these causes of death, the rates varied sufficiently by year to preclude assessment of this trend over such a short time period.

Table 2. Work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994 by occupation and year.

		Average rate (1990–1994)			Rate by year					Change in rate[e]
BOC code	and occupations[a]	N[b]	R[c]	95% CI[d]	90	91	92	93	94	(%)
All	Construction industry	4661	12.7	12.6–12.8	13.9	12.5	12.6	12.1	12.3	–12.0
577	Electrical power Installers and repairers	49	96.6	79.3–123.7	109.7	61.6	70.0	117.9	120.1	9.5
597	Structural metal workers	174	86.4	77.4–97.8	70.5	79.7	107.5	77.1	105.6	49.7
844	Operating engineers	309	41.0	38.7–43.7	50.8	44.4	38.0	36.9	35.0	–31.0
598	Drillers, earth	28	34.8	29.3–42.8	41.1	40.2	—[g]	28.1	57.1	39.0
556	Supervisors; painters	18	34.5	27.9–45.2	30.8	—[g]	—[g]	84.6	—[g]	
869	Construction laborers	1133	34.0	33.0–35.0	37.2	29.2	37.1	33.0	33.3	–10.4
643	Boilermakers	12	33.0	26.3–44.5	—[g]	—[g]	—[g]	—[g]	—[g]	
216	Engineering technicians[NEC f]	18	29.8	24.4–38.2	—[g]	68.7	42.4	—[g]	—[g]	
783	Welders and cutters	102	28.5	26.2–31.3	27.1	31.3	24.0	36.7	25.0	–7.7
544	Millwrights	16	27.1	22.2–34.8	28.1	—[g]	—[g]	—[g]	49.6	76.2
516	Heavy equipment mechanics	57	23.2	21.0–25.9	12.4	19.1	25.1	35.1	26.1	111.2
543	Elevator installers	16	22.5	18.9–27.5	26.4	35.2	—[g]	25.8	—[g]	
557	Supervisors; plumbers	11	22.3	17.9–29.5	—[g]	—[g]	—[g]	43.6	—[g]	
595	Roofers	209	21.5	20.4–22.6	16.3	27.2	19.7	16.5	29.7	82.9
849	Crane and tower operators	19	20.5	17.6–24.5	20.1	28.0	—[g]	24.6	—[g]	

849	Crane and tower operators	19	20.5	17.6–24.5	20.1	28.0	—g	24.6	—g	
804	Truck drivers	159	19.3	18.3–20.5	28.3	16.4	24.4	17.5	11.4	–59.7
856	Industrial truck/tractor equipment operator	17	17.2	14.8–20.6	25.3	—g	—g	25.2	—g	
653	Sheet metal workers	31	17.0	15.2–19.4	21.4	21.8	12.6	12.3	15.2	–29.0
005	Administrators and officials	11	17.0	14.0–21.6	—g	—g	—g	—g	—g	
599	Construction trades,NEC	114	17.0	16.0–18.1	18.0	23.4	12.3	14.4	17.1	–5.1
558	Construction supervisors,NEC	392	15.1	14.6–15.6	17.3	16.4	15.1	15.4	11.7	–32.2
575	Electricians	261	14.4	13.9–15.0	17.1	10.2	16.0	14.2	14.5	–15.1
555	Supervisors; electricians	13	12.0	10.4–14.4	—g	—g	—g	—g	—g	
593	Insulation workers	29	11.9	10.7–13.3	17.0	29.9	—g	—g	9.1	–46.4
035	Construction inspectors	10	10.2	8.7–12.2	—g	—g	—g	—g	—g	
053	Civil engineers	38	10.2	9.4–11.1	14.6	10.1	5.3	13.3	7.6	–48.0
563	Brickmasons	84	10.1	9.5–10.7	11.6	11.3	6.2	10.5	10.6	14
588	Concrete finishers	33	9.9	9.1–10.8	11.5	9.2	19.3	—g	9.8	–8.9
576	Electrician apprentices	11	9.8	8.5–11.7	—g	—g	—g	—g	18.8	154.0
853	Excavation machine operators	33	9.1	8.4–10.0	8.1	9.4	6.5	11.2	10.4	28.1
585	Plumbers/pipefitters	131	8.8	8.5–9.2	10.3	7.2	11.6	6.8	8.2	–21.2
567	Carpenters	408	7.6	7.4–7.8	7.3	6.6	8.7	7.6	7.9	7.3
579	Painters	159	7.4	7.1–7.7	8.0	7.7	6.2	7.5	7.5	–6.5
866	Helpers, construction trades	29	5.8	5.4–6.3	9.9	4.0	6.0	—g	5.2	–47.8
022	Managers/administration, NEC	226	5.2	5.1–5.4	5.9	5.4	5.4	5.1	4.4	–24.5
855	Grader/dozer/scraper operators	15	4.4	4.1–4.9	5.6	6.0	—g	—g	5.9	3.7

Table 2. Work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994 by occupation and year. (continued)

BOC code and occupations[a]	Average rate (1990–1994)			Rate by year					Change in rate[e] (%)
	N[b]	R[c]	95% CI[d]	90	91	92	93	94	
534 Heat/air condition mechanics	27	3.8	3.6–4.1	4.1	—[g]	5.2	5.5	2.8	–31.8
573 Drywall installers	17	2.6	2.4–2.7	3.4	—[g]	—[g]	3.1	3.9	15.2

[a] Occupational codes were based on the *1990 Census of Population:Alphabetic Index of Industries and Occupations* (BOC, 1992).

[b] N: Number of occupational injury deaths for 1990 through 1994 from the National Traumatic Occupational Fatalities surveilance system maintained by the National Istitute for Occupational Safety and Health.

[c] R: Rate = Number of occupational injury deaths per 100,000 workers. The estimated number of employees used in the rate calculations were from the Current Population Survey (CPS) microdata maintained by the Bureau of Labor Statistics.

[d] Approximate 95% Confidence intervals are based on the standard errors for the employment estimates in the CPS as published in the *Employment and Earnings* (BLS, 1997).

[e] Change in rate: The net change in rate over the period expressed as a percent of the rate in 1990 $\{\Delta = ((1994 \text{ rate} - 1990 \text{ rate}) / 1990 \text{ rate}) \times 100\}$.

[f] NEC: Not elsewhere classified.

[g] Rates were not calculated when the number of deaths was ≤3.

Table 3. Cause-specific work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994 by year.

	1990		1991		1992		1993		1994		Change in rate[d]
Cause of death[a]	N[b]	R[c]	N	R	N	R	N	R	N	R	(%)
Falls	283	3.7	237	3.3	215	3.0	223	3.1	262	3.5	–4.6
Motor vehicle	206	2.7	138	1.9	177	2.5	181	2.5	162	2.2	–19.0
Electrocution	133	1.7	110	1.5	115	1.6	94	1.3	109	1.5	–16.0
Machine	131	1.7	119	1.7	100	1.4	118	1.6	94	1.3	–26.0
Struck by falling objects	82	1.1	69	1.0	63	0.9	60	0.8	53	0.7	–33.0
Suffocation	41	0.5	24	0.3	24	0.3	21	0.3	27	0.4	–32.0
Homicide	29	0.4	29	0.4	31	0.4	31	0.4	34	0.5	20.8
Explosion	26	0.3	25	0.4	16	0.2	14	0.2	23	0.3	–8.9
Struck by flying objects	27	0.3	14	0.2	21	0.3	19	0.3	19	0.3	–28.0
Nature/environment	28	0.4	27	0.4	28	0.4	30	0.4	38	0.5	–33.0
Drowning	20	0.3	11	0.2	11	0.2	11	0.2	13	0.2	–33.0
Fires	16	0.2	15	0.2	11	0.2	9	0.1	7	0.1	–55.0
Poisoning	15	0.2	8	0.1	11	0.2	6	0.1	21	0.3	44.2

Table 3. Cause-specific work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994 by year. (continued)

	1990		1991		1992		1993		1994		Change in rate[d]
Cause of death[a]	N[b]	R[c]	N	R	N	R	N	R	N	R	94–90 (%)
Suicide	14	0.2	16	0.2	12	0.2	20	0.3	15	0.2	10.4
Other incidents	11	0.1	35	0.5	34	0.5	33	0.5	28	0.4	162.0
Other transportation	11	0.1	12	0.2	7	0.2	11	0.2	12	0.2	12.7
Intent Unknown	4	0.1	2	0.0	3	0.0	3	0.0	3	0.0	–23.0

[a] Cause of Death: External cause-of-death (E-800 through E-999) from the *International Classification of Disease* (WHO, 1977).

[b] N: Number of occupational injury deaths for 1990 through 1994 from the National Traumatic Occupational Fatalities surveillance system maintained by the National Institute for Occupational Safety and Health.

[c] R: Rate = Number of occupational injury deaths per 100,000 workers. The estimated number of employees used in the rate calculations were from the Current Population Survey (CPS) microdata maintained by the Bureau of Labor Statistics.

[d] Change in rate: The net change in rate over the period expressed as a percent of the rate in 1990 $\{\Delta = ((1994\ \text{rate} - 1990\ \text{rate}) / 1990\ \text{rate}) \times 100\}$.

Table 4 presents cause- and occupation-specific rates and their associated working lifetime-risk estimates for occupations that had 150 or more deaths during the 5 years. The highest rate for falls occurred among structural metal workers (54.1/100,000 construction workers), more than 16 times the average rate of 3.3 for falls in construction, followed by roofers (14.7) and construction laborers (7.4). The highest rate for motor-vehicle incidents occurred among truck drivers (12.3), five times the average of 2.4 for motor-vehicle-related incidents in construction, followed by operating engineers (10.1) and construction laborers (8.0). The highest rate for machinery incidents occurred among operating engineers (15.5), 10 times the average of 1.5 for machinery incidents in construction, followed by structural metal workers (7.9) and construction laborers (3.8). The highest rate for electrocution occurred among electricians (6.6), more than four times the average of 1.4 for electrocution in construction, followed by structural metal workers (4.5) and construction laborers (3.1). Ten cause- and occupation-specific combinations in Table 4, have working lifetime risks equal to or exceeding 3 deaths per 1,000 working lifetimes. The highest working lifetime risks are for falls among structural metal workers (24.1), machinery incidents among operating engineers (7.0), falls among roofers (6.6), and motor-vehicle incidents among truck drivers (5.5) and operating engineers (4.5).

State-specific fatal work-related-injury rates are provided in Table 5. The District of Columbia, Wyoming, Alaska, West Virginia, North Dakota, and South Carolina had the highest rate over the 5-year period. Most of the Mountain, Central and Southern states had rates above the national average. The lowest rates were found in the northeast and the States of Arizona, Ohio, Washington, Michigan and California.

DISCUSSION

This study has reviewed work-related fatal injuries to all occupations within the construction industry and is the first report providing a comprehensive national profile of work-related fatal injuries in the construction industry by occupation and cause of death in the United States. Pollack *et al.* (1996) published work-related fatality rates in construction for selected occupations or occupation groups using 1992 to 1993 CFOI data and CPS data. They used full-time equivalent workers as a denominator to calculate rates, which takes hours-worked into consideration when estimating exposure (Pollack *et al.*, 1996; Ruser, 1998). In spite of differences in data sources used to identify work-related fatalities and the definition of the denominator, results from our study closely agreed with Pollack's study. But some high-risk occupations were identified in our study that were not identified in their study, such as construction supervisors; truck drivers; engineering technicians; boilermakers; earth drillers; welders and cutters; elevator installers; and heavy-equipment mechanics. Pollack *et al.* (1996) grouped electricians with electrical-power installers and repairers, an occupation that, in this study, had a fatality rate more than six times the rate for electricians.

Table 4. Occupation- and cause-specific work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994.

	Falls		Motor Vehicle		Machinery		Electrocution		Struck by Falling objects	
Occupations[b]	R[c]	WLTR[d]	R	WLTR	R	WLTR	R	WLTR	R	WLTR
All Occupations	3.3	1.5	2.4	1.1	1.5	0.7	1.4	0.7	0.9	0.4
Structural metal workers	54.1	24.1	1.5	0.7	7.9	3.6	4.5	2.0	7.4	3.3
Operating engineers	1.5	0.7	10.1	4.5	15.5	7.0	1.6	0.7	3.9	1.7
Construction Laborers	7.4	3.3	8.0	3.6	3.8	1.7	3.1	1.4	3.2	1.4
Roofers	14.7	6.6	1.5	0.7	0.4	0.2	2.0	0.9	0.1	0.0
Truck drivers	0.4	0.2	12.3	5.5	2.1	0.9	1.0	0.4	1.1	0.5
Electricians	3.1	1.4	1.2	0.5	1.0	0.4	6.6	3.0	0.2	0.1
Construction Supervisors	4.0	1.8	3.4	1.5	1.6	0.7	1.6	0.7	0.8	0.4
Carpenters	3.2	1.5	0.6	0.3	0.5	0.2	0.8	0.3	0.7	0.3
Painter	3.7	1.7	0.5	0.2	0.2	0.1	1.0	0.5	0.2	0.1
Managers and administrators	1.2	0.5	1.0	0.4	0.7	0.3	0.5	0.2	0.2	0.1

[a] Cause of Death: External cause-of-death (E-800 through E-999) from the International Classification of Disease (WHO, 1977).

[b] Occupational codes were based on the 1990 Census of Population: Alphabetic Index of Industries and Occupations (BOC, 1992).

[c] R: Rate = Number of occupational injury deaths per 100,000 workers. The estimated number of employees fused in the rate calculations were from the Current Population Survey (CPS) microdata maintained by the Bureau of Labor Statistics.

[d] WLTR: Working lifetime risk expressed as the number of occupational injury deaths per 1000 workers over a 45-year working lifetime.

Table 5. State-specific work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994.

State	Employees[a]	Deaths[b]	Rates[c]	95 % CI[d]
District of Columbia	32,337	15	46.4	32.1 – 83.5
Wyoming	63,554	25	39.3	30.3 – 56.0
Alaska	66,895	24	35.9	27.9 – 50.2
West Virginia	173,918	50	28.7	24.3 – 35.3
North Dakota	68,026	19	27.9	21.8 – 39.0
South Carolina	438,549	120	27.4	24.6 – 30.9
Utah	202,010	50	24.8	21.3 – 29.6
Mississippi	312,825	73	23.3	20.6 – 26.9
Montana	105,048	24	22.8	18.6 – 29.6
South Dakota	79,620	18	22.6	17.9 – 30.6
Georgia	774,444	174	22.5	20.7 – 24.5
Kansas	283,846	63	22.2	19.5 – 25.8
New Mexico	203,051	45	22.2	19.0 – 26.5
Nebraska	183,353	39	21.3	18.1 – 25.8
Illinois	1,169,535	247	21.1	19.8 – 22.7
Texas	2,220,012	466	21.0	20.0 – 22.1
Arkansas	280,825	58	20.7	18.1 – 24.0
Louisiana	552,542	113	20.5	18.6 – 22.8
Alabama	526,449	107	20.3	18.4 – 22.6
Iowa	334,254	66	19.7	17.5 – 22.6
Idaho	158,515	31	19.6	16.5 – 24.0
Florida	1,743,166	332	19.0	18.0 – 20.2
Pennsylvania	1,296,323	231	17.8	16.7 – 19.1
Nevada	213,332	38	17.8	15.3 – 21.3
Missouri	603,019	107	17.7	16.2 – 19.6
North Carolina	864,982	144	16.6	15.4 – 18.1
Kentucky	431,633	71	16.4	14.8 – 18.5
Colorado	445,907	73	16.4	14.7 – 18.4
New York	1,680,163	261	15.5	14.7 – 16.5
Indiana	642,579	99	15.4	14.1 – 17.0
Tennessee	573,032	84	14.7	13.3 – 16.3
Oregon	370,517	53	14.3	12.8 – 16.3
New Jersey	793,096	111	14.0	12.9 – 15.3
Rhode Island	100,518	14	13.9	11.2 – 18.4

Table 5. State-specific work-related fatal-injury rates among U.S. construction workers who died from 1990 to 1994. (continued)

State	Employees[a]	Deaths[b]	Rates[c]	95 % CI[d]
Virginia	893,809	119	13.3	12.3 – 14.5
Oklahoma	319,066	42	13.2	11.6 – 15.2
Hawaii	184,715	24	13.0	11.1 – 15.7
Wisconsin	605,241	74	12.2	11.2 – 13.5
Minnesota	482,781	59	12.2	11.0 – 13.7
California	3,255,412	388	11.9	11.4 – 12.4
Michigan	901,828	107	11.9	11.0 – 12.9
Massachusetts	584,928	68	11.6	10.6 – 12.9
New Hampshire	140,650	16	11.4	9.5 – 14.3
Washington	680,334	71	10.4	9.6 – 11.5
Ohio	1,102,510	112	10.2	9.5 – 10.9
Maine	156,838	14	8.9	7.5 – 11.1
Delaware	103,336	9	8.7	7.1 – 11.3
Maryland	670,555	53	7.9	7.2 – 8.7
Arizona	478,392	33	6.9	6.2 – 7.7
Connecticut	335,084	22	6.6	5.8 – 7.6
Vermont	86,027	5	5.8	4.6 – 7.9

[a] Employees: estimated number of employees for 1990 through 1994 from the Current Population Survey (CPS) microdata maintained by the Bureau of Labor Statistics.

[b] Deaths: Number of occupational injury deaths for 1990 through 1994 from the National Traumatic Occupational Fatalities Surveillance system maintained by the National Institute for Occupational Safety and Health.

[c] Rate: Number of occupational fatal injury deaths per 100,000 workers.

[d] Approximate 95% Confidence intervals are based on the standard errors for the employment estimates in the CPS as published in the *Employment and Earnings* (BLS, 1997).

A previous study of work-related fatal injury among construction workers using NTOF data for the period of 1980 to 1989 (Kisner and Fosbroke, 1994) reported a rate of 21.7 / 100,000 workers in the construction industry in 1989, a rate that is nearly twice the average annual rate of 12.7 / 100,000 in this study. The reason for the difference in the fatal-injury rates between the two studies is the fact that the denominator used in Kisner and Fosbroke's study was obtained from the County Business Patterns, an establishment-based employment count developed by the Bureau of the Census, which does not include owner-operators. These excluded owner-operators make up a significant proportion of the construction industry. Kisner and Fosbroke (1994) reported fatality rates by occupation division and found that laborers had the highest rate of 39.5 in construction. The occupational divisions used in their study are not comparable to the detailed occupations used in this study, so laborers in their study are not comparable to construction laborers in this study.

Among the 38 occupations identified to have ten or more deaths during the 5 years, 33 are blue collar occupations (BOC occupational codes = 503 – 889). The 22 occupations identified as having a fatal-injury rate greater than the U.S. construction industry average, accounted for 35% of the industry's employment. However, deaths from these 22 occupations accounted for 68% of all work-related injury deaths in construction. The average rate for these 22 occupations is 24.9, while the rate in all of construction is 12.7. The ranking of occupations by fatal injuries should be used in setting research, regulatory, and prevention priorities for the construction industry. Setting such priorities requires consideration of the number of injuries (which provides a measure of the magnitude of the injury problem for an occupation) and the rate of injury (which provides a measure of injury risk for an occupation).

Special-trade occupations usually had a high incidence of work-related fatal injuries related to one or two specific causes of death. For example, electricians, and electrical power installers and repairers had a high injury rate of electrocution; truck drivers had a high rate of motor-vehicle- related deaths; and roofers had a high rate of fatal falls. In contrast, construction laborers experienced elevated risks for all causes of death, with the exception of death from air-transport-related incidents (results for other causes of death are not presented due to space constraints). The mortality patterns by occupation and cause of death presented in Table 4 should be useful for developing occupation-specific prevention programs. For example, a prevention program for structural-metal workers should focus on deaths from falls, machinery incidents, and electrocutions; and a prevention program for operating engineers should focus on deaths from machinery and motor-vehicle incidents. In contrast, a prevention program for construction laborers should cover a broad range of safety hazards.

Construction workers aged 30 to 34 years had the lowest fatality rates, while workers in the older age groups had the highest rates. Other studies have also found a higher risk of fatal injury among older construction workers (Buskin and Paulozzi, 1987; Kisner and Fosbroke, 1994; Kisner and Pratt, 1997). Warr (1993, 1994) discussed age-impairment as related to both age-related shortcomings and experience. While the relationship identified in this study between fatal injuries and age among construction workers may suggest that lack of experience among younger construction workers (20 to 29 years old) and age-related shortcomings among older construction workers (45 years or older) may be important risk factors, information on such age-related factors is not available in NTOF. Injury severity and age-related complications have also been cited as factors contributing to the high fatal-injury rates among older workers (Kisner and Pratt, 1997; Personic and Windau, 1995). Though older workers have high fatal-injury rates, they have low OSHA recordable injury rates, suggesting that when injured, older workers may have more serious outcomes (Personick and Windau, 1995). In their paper on fatalities among older workers, Kisner and Pratt (1997) provide a good review of the literature on the relationship between age and fatal-injury rates.

The construction industry in general experienced a decline in work-related fatal-injury rate over the years of 1980 to 1989 (Stout, Jenkins, and Pizatella, 1996). This decline continued into the 1990's. However, the decline of the fatality rate did not occur equally across occupations and causes of death over the period from 1990 to 1994. The causes of death and the occupations that had a rate decline may be indicative of the effectiveness of recent regulatory changes, current prevention programs, or other positive changes in working practices or environments. The causes of death and the occupations that had little change in fatality rates may indicate a need for improvement of current working practices or environments.

NIOSH has reported that the construction industry accounted for the largest number of work-related-injury deaths in 19 states and was the highest risk industry in three states (CDC, 1998). The geographic variation in fatal injuries in construction presented in Table 5 generates questions for future research. Potential factors that might contribute to this geographic variation are geographic differences in the type of construction, the type of equipment used, weather and economic conditions, union and population density, pre-hospital care availability, workforce experience, and implementation of safety and health programs. Unfortunately, information on these risk factors is not available in NTOF data. The states with the highest construction-fatality rates should clearly be the focus of enhanced injury-prevention efforts.

Fosbroke *et al.* (1997) recently applied the concept of working lifetime risk to fatal occupational injury studies, which facilitates the comparison of occupational injury risks with risk assessments for occupational disease. They suggested that risk assessments for occupational injuries and occupational illnesses should be considered equally with each other (Fosbroke *et al.*, 1997). The industry-wide (all occupations in construction combined) working lifetime-risk estimates for the five leading causes of death ranged from 0.4 to 1.4 in 1000 working lifetimes (Table 4), levels that are below, or near, the one death in 1,000 working lifetimes that OSHA uses as an indicator of significant hazard. However, for each of these five causes of death, there are specific subgroups of construction workers who face considerably higher working lifetime risks of fatal injury on the job. Ten occupation-by-cause-of-death combinations had lifetime risk estimates of at least 3 times OSHA's measure of significant hazard (Table 4). Another ten combinations had lifetime-risk estimates between 1.4 and 2.0 times greater than OSHA's measure of significant hazard. While regulatory action is underway with respect to some of these injury exposures (*e.g.*, falls among structural metal workers is an emphasis of the negotiated rulemaking on steel erection), other injury hazards (*e.g.*, motor-vehicle risk to operating engineers and construction laborers) are not covered by specific OSHA construction standards.

LIMITATIONS

Many authors have reviewed the limitations of using death certificates in general and NTOF data in particular for the study of fatal occupational injury. These limitations should be kept in mind when interpreting the results of this study. Of particular concern is the use of usual industry and usual occupation, rather than the industry and occupation at the time of injury (Steenland and Beaumont, 1984) and the accuracy of the injury-at-work item on death certificates (Russell and Conroy, 1991). The result of these limitations is that some worker populations and causes of death are underrepresented in occupational studies based on death certificates. Even with the limitations of death certificates and NTOF for studies such as this, death certificates are the single document source that capture the greatest proportion of work-related fatal injuries, approximately 80% (Stout and Bell, 1991), and the NTOF surveillance system provides the most detailed data on fatal occupational fatalities during the study period, 1990 to 1994.

In 1992, the Bureau of Labor Statistics introduced the Census of Fatal Occupational Injuries (CFOI). Though CFOI provides a more comprehensive capture of work-related injury than NTOF (due to its multiple source documents), results from CFOI should be similar to results from NTOF because approximately 80% of the cases in CFOI have a death certificate as one of the source documents (Drudi, 1995). However, differences in the way the cause of death is classified would yield slightly different results, because CFOI uses the event or exposure leading to injury or illness as defined in the Occupational Injury and Illness Classification System (OIICS) (ANSI, 1995) rather than the cause of death as defined in the International Classification of Diseases-Ninth Revision (WHO 1977). This study builds on the literature developed from NTOF throughout the 1980s and early 1990s, using the same cause-of-death classification system used by these earlier studies. Another limitation of this study is that results for certain occupation categories in this study should be interpreted with caution because of the small number of deaths. To obtain reliable fatal-injury rates and lifetime-risk estimates for occupations with a small annual number of deaths, continual data collection over a number of years is essential. An alternative might be to group these occupational categories; however, work needs to be done to determine occupational groupings which are logical in terms of injury prevention.

The WLTR estimates provided in this paper represent an average risk to fatal injuries of the construction population, expressed as the number of deaths per 1000 working lifetimes. Though the equation presumes working lifetime of 45 years, the rate estimates used in the WLTR equation was not limited to workers of specific ages (*e.g.*, workers less than 20 years old and older than 65 years old are include in the calculation of R). The WLTR equation is simplistic—it is not intended to predict the actual risk of an individual who works at a given occupation for 45 years. In fact, the equation assumes that exposures to fatal injuries, though unknown, are constant over time. Any future changes in risk are not accounted for by the equation. In this paper, the average annual rate from 1990 through 1994 was used as an estimate of the fatal injury risk experienced in the construction industry and this risk estimate was assumed to be constant over time. This multi-year average limits the effect of year-to-year variations in fatal-injury rates on the resulting working lifetime risk estimates.

The WLTR equation does not change rankings developed using fatal injury rates. WLTR estimates are calculated because they can be expressed in a manner that is comparable to lifetime risk estimates previously developed for occupational illnesses, something that annual injury rates cannot be used for. Though a WLTR estimate can be calculated whenever a rate is calculated, to be meaningful, the WLTR estimate should be calculated for a specific cause of injury for a specific population. For example, it is appropriate to compare electrocution among carpenters with lung cancer among uranium miners, but it is not appropriate to compare all fatal injuries among carpenters to lung cancer among miners. Therefore, WLTR estimates were not provided for univariate variables, such as age, occupation, state, and cause of death.

CONCLUSIONS

Although construction has experienced a decline in its fatal-injury rate since 1980, it remains one of the most dangerous industries in the United States: on average, 2.6 construction workers were killed from on-the-job injury every day in the United States during the years of 1990 to 1994. The severity of the fatal-injury problem in this industry is clearly described in the National Occupational Research Agenda (NORA) document (NIOSH, 1996). The NORA document calls for moving the Nation's research effort from the broad generalities of national burden of disease and injury, to the specifics of targeted-intervention programs. The findings of this paper support the call for targeted, specific research by defining fatal-injury risk for specific occupations and causes of death within the high-risk construction industry, identifying differences in state-specific construction-injury rates, and demonstrating variability in fatal-injury risks and patterns of fatal injury across occupations within the construction industry. The study's results indicate where improvements in working practices and environments in the construction industry are urgently needed and can be used to tailor occupation-specific injury prevention programs.

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