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Working Lifetime Risk of Occupational Fatal Injury

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Estimates of risk accumulated over a working lifetime are used to assess the significance of many workplace health hazards. Utilizing data from the National Traumatic Occupational Fatalities (NTOF) surveillance system, estimates of the risk of work-related fatal injuries are provided for the 50 industries and the 50 occupations having the highest risks. Cause-specific risk estimates are provided for the six occupations at the greatest risk of occupational fatal injuries. Results suggest that the risks of certain work-related fatal injuries in some occupations (e.g., loggers being struck by falling objects) are of the same magnitude as risks previously identified for specific occupational illness exposures (e.g., lung cancer among uranium miners exposed to ionizing radiation). Assuming a 45-year working lifetime, cause-specific fatal injury risks reported in this paper range from a predetermined minimum of 1 death per 1,000 lifetime workers to 36.4 deaths per 1,000 lifetime workers. These results suggest that risk assessment for traumatic causes of death should be considered equally with risk assessments for health exposures, such as potential carcinogens. Am. J. Ind. Med. 31: 459–467, 1997. *© 1997 Wiley-Liss, Inc.*†

KEY WORDS: occupational fatal injury; lifetime risk; occupation; industry; cause-specific risk

INTRODUCTION

The public-health literature contains many publications that attempt to define the relative risk of workers in different industries or occupations. These studies range from estimating the elevated numbers of deaths from certain illnesses or injuries for specific workers (e.g., proportionate mortality studies, standardized mortality studies) [Robinson et al., 1995; Singleton and Beaumont, 1989; Commonwealth of Pennsylvania, 1987; Mace, 1986; Milham, 1983] to estimating a worker's lifetime risk of dying of a stated illness based on exposure to a hazard in a specific job [Palmer and Rickett, 1992; Nurminen et al., 1992; Stayner et al., 1992; Smith and Stayner, 1990; Hodgson and Jones, 1990; Friedberg et al., 1989; Dong et al., 1988; NIOSH, 1987; Purchase et al., 1987; Siegel et al., 1983].

Lifetime risk assessments are useful studies of risk because of their utility for setting priorities on hazardous exposures for developing interventions. The concept of lifetime risk also has a second critical value associated with regulatory use as a basis for defining whether a particular hazard is significant [Stayner, 1992]. Currently, the Occupational Safety and Health Administration (OSHA) considers a lifetime risk of 1 death in 1,000 workers to be a significant level of risk to justify standards development, especially for cancer-causing agents [Stayner, 1992; Adkins, 1993].

This concept of lifetime risk has not been widely applied to occupational injury deaths. The reasons for this include the lack of sufficient detail in data records to define the workers' detailed occupation and the cause of the workers' death, as well as a tendency to focus on annual fatality rates for defining a workers' risk of fatal injury. Publications have defined annualized fatal injury rates by detailed occupation [Leigh, 1987, 1988; Meng, 1991] while other research has defined industry and occupation risk in less detail or for a small number of selected occupations [Jenkins et al., 1993; Toscano and Windau, 1995a,b]. Leigh [1995] reported detailed industry and occupation rates for injuries and illnesses combined and provides the number of deaths by cause associated with each fatality rate. However,

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these papers have not attempted to define the concept of lifetime risk for detailed industries and occupations, or provided cause-specific lifetime risk estimates based on annualized fatality rates.

The purpose of this work was to examine the use of lifetime risk based on national fatality data from the National Institute for Occupational Safety and Health (NIOSH) National Traumatic Occupational Fatalities (NTOF) surveillance system. The main research objectives of the study were to define the general lifetime risk of occupational injury death within detailed industries and occupations, and to define cause-related lifetime risks for those occupations identified as having the highest general lifetime risks. While annual rates and lifetime risk estimates produce equivalent assessment of risk, this paper uses a lifetime risk model for injury that can be compared with risk assessments for occupational illnesses.

METHODS

The data source used to define occupational fatalities was the NIOSH NTOF for the calendar years 1990 and 1991. The NTOF data were collected as a census of death certificates from all 52 Vital Statistics reporting agencies in the U.S. Inclusion criteria for the NTOF were: (1) death resulting from an external cause of injury (E-codes 800–999) according to the International Classification of Diseases, Ninth Revision (ICD-9) [World Health Organization, 1977], (2) victim's age at least 16, and (3) a positive response to the death certificate's 'Injury at Work?' item.

Numerous publications have described the NTOF system, its methods, and its limitations. The most recent description summarizes data for the decade of the 1980s [Jenkins et al., 1993]. Since NTOF is death-certificate based, interpretation of results presented in this paper should consider the limitations of death certificates for ascertaining work-related fatal injuries, including errors of omission and misclassification [Bell et al., 1990], recording of usual industry and occupation [Steenland and Beaumont, 1984], and underreporting of occupational motor vehicle-related deaths [Russell and Conroy, 1991].

In spite of the limitations, Stout and Bell [1991] report an average capture rate of 81% for death certificates used in ten studies of work-related fatal injury. The NTOF surveillance system used in this study provides the most detailed data on occupational fatal injuries during the study period of 1990 through 1991.

The 1990 and 1991 NTOF data were manually coded for detailed industry and occupation codes using the Bureau of the Census (BOC) 1980 classification system [1982]. Data prior to 1990, which had been coded using a 1987 computer algorithm accurate only at the industry and occupation division level [Castillo and Jenkins, 1994], were not used in this study. Denominator data were obtained from the 1990 and 1991 annual employment averages published by the BLS in Employment and Earnings, which are based on the Current Population Survey [BLS 1991, 1992]. For some occupations, detailed employment data were not published in Employment and Earnings. These occupations were combined with other occupations using the 1980 BOC hierarchy of codes, which allowed employment estimates to be calculated. A list of combined occupation codes are presented in Table I. Annualized rates were calculated on a per 1,000 full-time worker basis to facilitate comparison with reported rates for illnesses.

TABLE I. Bureau of the Census Occupation Codes That Have Been Combined to Match Employment Information from the Bureau of Labor Statistics and Were Among the Fifty Most Injury Hazardous Occupations

Combined code	Occupation	1980 Bureau of Census codes
S450	Other Building Services Occupations	454, 455
S473	Farmers	473, 474
S475	Farm Managers	475, 476
S488	Other Agriculture-Related Occupations	488, 489
S490	Other Forestry & Logging Occupations	494, 495
S497	Fishing Hunting Trapping Occupations	497, 498, 499
S504	Other Vehicle Mechanics	506, 515, 517
S558	Construction Supervisors	553, 554, 555, 556, 557, 558
S599	Other Construction Trades Occupations	569, 576, 583, 584, 587, 589, 594, 596, 598, 599
S617	Extractive Occupations	613, 614, 615, 616, 617
S655	Other Precision Metal Workers	635, 636, 639, 643, 644, 645, 646, 649, 654, 655
S699	Other Plant & System Operators	695, 699
S826	Rail Transport Occupations	823, 824, 825, 826
S830	Water Transport Occupations	828, 829, 833, 834
S859	Other Material Moving Occupations	843, 845, 848, 859
S868	Other Helpers	866, 867

The lifetime risk for a specific industry or occupation was calculated using an equation proposed by the Occupational Safety and Health Administration [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; $1 - R$ = probability of a worker not having a work-related fatal injury in a given year; y = years of exposure to work-related injury; $(1 - R)^y$ = probability of

surviving ‘y‘ years without a work-related fatal injury; $1 - (1 - R)^y$ = probability of having a work-related fatal injury over ‘y‘ years of employment.

In this study, y was set at 45 years. This assumes that workers are exposed to work-related injury hazards for approximately 45 years, starting at age 20. This time period is consistent with work-life values used in many quantitative risk assessments for occupational illnesses [Stayner, 1992]. The lifetime risk formula estimates the average lifetime risk for workers in a given occupation or industry. The formula does not predict an individual’s probability of fatal injury given his/her occupation.

The lifetime risk formula also assumes that exposure to fatal occupational injury is constant over a 45-year period. Though an individual’s risk may vary over any given 45-year period and the risk of fatal injury varies by demographic characteristics (e.g., age), the average annual fatality rate for an occupation is determined by the risk of all individuals comprising the occupation at a point in time. The above formula assumes that this average risk remains constant for a working lifetime, which is necessary to project a lifetime risk estimate comparable to risk estimates for occupational illness.

The ICD-9 E-codes for the six occupations with the highest general lifetime risk were examined to determine cause-specific lifetime risks that were greater or equal to 1 death per 1,000 workers.

RESULTS

Table II presents the 1990–1991 fatality counts, annualized fatality rates, and general lifetime risk values for the 50 highest-risk industries in the United States. Data for other industries are available from the authors. The industry with the highest lifetime risk was Logging (BOC Industry code 230), followed by Commercial Fishing, Hunting, and Trapping (code 031), Taxicab Service (code 402), Coal Mining (code 041), and Water Transportation (code 420). The highest number of fatalities were reported in Construction (code 060), followed by Trucking Service (code 410), Agricultural Crop Production (code 010), Logging (code 230), and Justice, Public Order, and Safety (code 910).

Table III presents the general lifetime risks for the 50 most hazardous occupations. Data for additional occupations are available from the authors. The six highest risk occupations were Timber Cutting and Logging Occupations (BOC Occupation code 496), Fishers, Hunters, and Trappers (codes 497, 498, and 499), Water Transportation Occupations (codes 828, 829, 833, and 834), Structural Metal Workers (code 597), Extractive Occupations (codes 613, 614, 615, 616, and 617), and Airplane Pilots (code 226). The occupation with the most fatalities was Heavy Truck Drivers (code 804), followed by Farmers (codes 473 and 474), Construction Laborers (code 869), Timber Cutting and Logging Occupations (code 496), Construction Supervisors (codes 553, 554, 555, 556, 557, and 558), and Farm Workers (codes 477, 483, and 484).

The causes of death that were associated with lifetime risks greater or equal to 1 death per 1,000 lifetime workers are presented in Table IV. These values are only for the six highest risk occupations identified in Table III.

Among these six occupations, the highest cause-specific lifetime risk occurred among workers in Timber Cutting and Logging Occupations being struck by falling objects (36.4 deaths/1,000 lifetime workers), followed by Airplane Pilots killed in other and unspecified accidents to an aircraft (e.g., non-landing or take-off plane crash, explosion on plane, collision with birds) (21.1 deaths/1,000 lifetime workers). Cause-specific lifetime risks greater than 10 deaths/1,000 lifetime workers were also identified for Fishers, Hunters, and Trappers. These were drownings associated with water transportation (14.1 deaths/1,000 lifetime workers) and watercraft accidents causing submersion (11.9 deaths per 1,000 workers).

DISCUSSION

High-Risk Industries and Occupations

The identification of high-risk industries and occupations, presented on Tables II and III, respectively, agree closely with other studies that have reported annualized fatality rates by industry or occupation in the U.S. [Leigh, 1987, 1988, 1995; Toscano and Windau, 1995a,b]. Variance between the results of these earlier studies and the NTOF-based rates presented here is due mostly to differences in the data sources used to identify occupational fatalities and the time periods covered by these studies. The studies by Leigh [1987, 1988, 1995] were based on workers’ compensation records, which miss industries, such as commercial fishing and agricultural production (both crop and livestock), that states generally do not require to have workers’ compensation insurance [Chamber of Commerce, 1991]. Occupations that were highly associated with these industries missed by workers’ compensation (e.g., fishers, farmers) were underreported or excluded from Leigh’s analyses—a limitation acknowledged by Leigh in his works. Leigh [1995] includes fatalities resulting from both injuries and illnesses in calculation of work-related fatality rates; therefore, Leigh identifies some occupations (e.g., stone cutters and carvers) with high rates due to illness, but few or no fatal injuries.

The annualized rates reported by Toscano and Windau [1995a,b] were based on the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) surveillance system. The CFOI has an advantage over the NTOF surveillance system in that the CFOI uses multiple

TABLE II. The Fifty Highest Fatal Injury Risk[a] Industries in the United States for 1990 and 1991 Based on the 1980 Bureau of the Census Industry Coding System. Lifetime Risk Assumed a 45-Year Work Life

BOC code	Industry	1990–1991 deaths	1990–1991 annual rate[b]	Lifetime risk[b]
230	Logging	318	1.07071	47.0641
031	Fish/Hunt/Trapping	148	0.92500	40.7891
402	Taxicab Service	109	0.48230	21.4748
041	Coal Mining	129	0.42857	19.1050
420	Water Transportation	135	0.36585	16.3316
010	Agricultural Production: Crops	635	0.31878	14.2447
040	Metal Mining	33	0.25000	11.1883
042	Oil/Gas Extraction	195	0.24164	10.8160
410	Trucking Service	760	0.20197	9.0482
050	Nonmetal Mine/Quarries	36	0.16071	7.2066
531	Scrap/Waste Materials	52	0.15710	7.0451
030	Forestry	23	0.13772	6.1789
060	Construction	1952	0.13204	5.9247
231	Sawmills/Planing Mills/Millwork	101	0.12965	5.8178
400	Railroads	76	0.12709	5.7031
551	Farm Products-Raw Materials	24	0.12632	5.6684
741	Detective/Protective Services	97	0.12565	5.6385
200	Petroleum Refining	36	0.11726	5.2633
471	Sanitary Services	67	0.11693	5.2483
270	Blast Furnaces/Steel Works	85	0.11214	5.0337
552	Petroleum Products	35	0.11182	5.0196
751	Auto Repair	224	0.10964	4.9220
421	Air Transportation	156	0.10841	4.8668
672	Fuel Dealers	25	0.10776	4.8377
021	Landscape/Horticulture Services	140	0.10550	4.7365
191	Agricultural Chemicals	9	0.09677	4.3456
360	Ship/Boat Building	48	0.09091	4.0827
561	Farm Supplies	23	0.08846	3.9730
020	Agricultural Services, NEC	53	0.08576	3.8520
011	Agricultural Production: Livestock	211	0.08567	3.8478
621	Gas Service Stations	82	0.08515	3.8246
650	Liquor Stores	22	0.07885	3.5422
110	Grain Mill Products	22	0.07639	3.4317
251	Cement/Concrete/Gypsum	30	0.07614	3.4207
851	Vocational Schools	10	0.07092	3.1865
450	Electric Light/Power	99	0.06962	3.1281
760	Misc. Repair Services	70	0.06869	3.0866
401	Bus Service/Urban Transit	62	0.06561	2.9481
272	Primary Aluminum	17	0.06320	2.8399
532	Misc. Wholesale, Durables	18	0.06186	2.7797
101	Dairy Products	19	0.05901	2.6518
660	Jewelry Stores	22	0.05851	2.6296
910	Justice/Public Order/Safety	238	0.05843	2.6261
440	Radio/TV Broadcasting	30	0.05803	2.6079
901	General Government, NEC	69	0.05623	2.5274
470	Water Supply/Irrigation	24	0.05581	2.5085
411	Warehousing/Storage	15	0.05376	2.4165
611	Food Stores, NEC	21	0.05371	2.4140
192	Industrial/Misc. Chemicals	63	0.05259	2.3637
891	Noncommercial Educ/Scientific Research	16	0.05195	2.3349

[a]Deaths are from the National Traumatic Occupational Fatalities (NTOF) Surveillance System and employment is from the Bureau of Labor Statistics ''Employment and Earnings'' annual averages.
[b]Rates in units per 1,000 full-time workers.

TABLE III. The Fifty Highest Fatal Injury Risk[a] Occupations in the United States for 1990 and 1991 Based on the 1980 Bureau of the Census Occupation Coding System. Lifetime Risk Assumed a 45-Year Work Life

BOC[b] code	Occupation	1990–1991 deaths	1990–1991 annual rate[c]	Lifetime risk[c]
496	Timber Cutting/Logging	256	1.43820	62.7129
S497	Fishing Hunting Trapping Occupation	131	1.07377	47.1956
S830	Water Transport Occupations	103	0.91150	40.2058
597	Structural Metal Workers	77	0.66957	29.6908
S617	Extractive Occupations	193	0.65646	29.1182
226	Airplane Pilots	135	0.62791	27.8690
844	Operating Engineers	174	0.40000	17.8425
577	Electrical Power Installers/Repairers	86	0.36596	16.3362
809	Taxicab Drivers/Chauffers	136	0.33831	15.1111
869	Construction Laborers	485	0.32904	14.7000
804	Truck Drivers (Heavy)	1097	0.28560	12.7717
S473	Farmers	602	0.27326	12.2232
S859	Other Material Moving Occupations	63	0.27273	12.1994
S490	Other Forestry & Logging Occupations	17	0.26984	12.0710
423	Sheriffs, Bailiffs	49	0.21304	9.5422
595	Roofers	85	0.20936	9.3779
544	Millwrights	35	0.20349	9.1161
S826	Rail Transport Occupations	44	0.18803	8.4266
199	Athletes	27	0.17881	8.0148
S558	Construction Supervisors	208	0.16417	7.3609
519	Machinery Maintenance Occupations	8	0.16327	7.3206
516	Heavy Equipment Mechanics	50	0.15674	7.0290
S599	Other Construction Trade Occupations	123	0.14784	6.6311
S504	Other Vehicle Mechanics	16	0.14414	6.4660
885	Garage, Service Station Occupations	60	0.14052	6.3037
727	Sawing Machine Operators	27	0.13706	6.1490
575	Electricians	186	0.13527	6.0692
418	Police and Detectives (Public)	128	0.13361	5.9949
783	Welders and Cutters	143	0.12522	5.6194
S699	Other Plant and System Operators	22	0.12155	5.4550
S479	Farm Workers	206	0.11880	5.3321
849	Crane and Tower Operators	20	0.11561	5.1891
563	Brickmasons/Stonemasons	39	0.10864	4.8769
588	Concrete Terrazzo Finishers	15	0.10791	4.8446
653	Sheet-Metal Workers	26	0.10700	4.8035
757	Separating Machine Operators	13	0.10656	4.7839
S868	Other Helpers	2	0.10000	4.4901
853	Excavating Machine Operators	20	0.09852	4.4239
426	Guards and Police (Private)	131	0.09675	4.3445
696	Stationary Engineers	21	0.09459	4.2479
417	Firefighters	38	0.09383	4.2135
S655	Other Precision Metal Workers	26	0.08935	4.0127
657	Cabinet Makers	9	0.08182	3.6752
S488	Other Agriculture-Related Occupations	3	0.08108	3.6421
S475	Farm Managers	23	0.08070	3.6251
527	Telephone Line Installers/Repairers	10	0.07937	3.5652
505	Automobile Mechanics	136	0.07879	3.5396
585	Plumbers/Pipefitters/Steamfitters	70	0.07821	3.5135
218	Surveying/Mapping Technicians	11	0.07746	3.4800
S450	Other Building Service Occupations	8	0.07692	3.4557

[a]Deaths are from the National Traumatic Occupational Fatalities (NTOF) Surveillance System and employment is from the Bureau of Labor Statistics ''Employment and Earnings'' annual averages.

[b]Occupation codes preceeded by the letter ''S'' are combinations of similar BOC occupation codes (see Table I).

[c]Rates are in units per 1,000 full-time workers.

TABLE IV. Causes of Death, by the Six Highest Fatal Injury Risk[a] Occupations, That Have a Lifetime Risk of 1 Death per 1,000 Workers or Greater, Based on Data for 1990 and 1991. Lifetime Risk Assumed a 45 Year-Work Life

Occupation	Cause of death	ICD-9	Lifetime risk[b]
Timber Cutting/Logging Occupations (BOC 496)	Struck by Falling Object	E916	36.4
	Machinery	E919	6.4
	Struck by or Against Object	E917	3.4
	Electric Current	E925	1.5
	Assault by Firearms	E965	1.5
	Cutting/Piercing Equipment	E920	1.2
Fishing, Hunting, Trapping Occupations (BOC 497, 498, 499)	Drowning in Water Transport	E832	14.1
	Accident to Watercraft Causing Submersion	E830	11.9
	Drowning, Submersion	E910	5.8
	Other Accident to Aircraft	E841	1.4
	Water Transport Unspecified Fall	E835	1.0
	Water Transport Machinery	E836	1.0
	Machinery	E919	1.0
Water Transport Occupations (BOC 828, 829, 833, 834)	Drowning in Water Transport	E832	7.0
	Drowning, Submersion	E910	4.7
	Accident to Watercraft Causing Submersion	E830	3.9
	Water Transport Fall, 1 Level to Other	E834	2.7
	Fire on Watercraft	E837	2.7
	Machinery	E919	2.3
	Struck by Object	E917	1.6
	Accident to Watercraft Causing Other Injuries	E831	1.2
Structural Metal Workers (BOC 597)	Fall from Building	E882	8.0
	Fall from 1 Level to Other	E884	4.6
	Fall from Ladder, Scaffold	E881	3.4
	Struck by Falling Object	E916	3.0
	Electric Current	E925	2.3
	Machinery	E919	1.9
Extractive Occupations (BOC 613, 614, 615, 616, 617)	Struck by Falling Object	E916	7.8
	Machinery	E919	6.3
	Explosive Material	E923	2.4
	Electric Current	E925	1.7
Airplane Pilot (BOC 226)	Other Accident to Aircraft	E841	21.1
	Accident During Takeoff or Landing	E840	3.3

[a]Deaths are from the National Traumatic Occupational Fatalities (NTOF) Surveillance System and employment is from the Bureau of Labor Statistics ''Employment and Earnings'' annual averages.
[b]Rates in units per 1,000 full-time workers.

record sources to identify work-related deaths, which improves the capture rate of the CFOI. Still, the results from the CFOI data for 1993 and 1994 tend to identify the same high-risk occupations as identified on Table III.

The main difference between the NTOF and the CFOI occupation-specific results was the identification of commercial fishermen as being the highest-risk occupation by the CFOI rather than timber cutting and logging occupations. Employment data were not available for just fishermen in the 1990 and 1991 *Employment and Earnings* [Bureau of Labor Statistics, 1991, 1992], thus fishermen were combined with commercial hunters and trappers in this NTOF study. The 1993 CFOI annualized fatality rate for fishers, hunters, and trappers was also higher than the rate for logging, which could be due to the better capture rate of fatality cases in the CFOI over the NTOF surveillance system.

Comparisons between the NTOF and the CFOI for high-risk industries were not possible because the CFOI results reported by Toscano and Windau [1995a,b] did not provide detailed industry rates. The 1993 CFOI results also contain a miscalculated rate for agricultural services. The 1993 agricultural services employment estimate should have been 1,079,000 workers [Bureau of Labor Statistics, 1995], rather than the reported 165,000 workers. Using the correct employment estimate lowers the agricultural services fatality rate from 94 deaths per 100,000 workers to 14 deaths per 100,000.

Even with the differences in data sources, time periods covered, and employment numbers used by Leigh, Toscano and Windau, and this study, the list of occupations at highest risk for fatal work injuries are very similar. Timber cutting and logging occupations, airplane pilots, structural metal workers, taxicab drivers, and electrical linemen are consistently identified to be occupations with high fatality rates. Toscano and Windau and this study also identified fishing, hunting, and trapping occupations, and farm operators, as having high fatality rates.

Cause-Specific Lifetime Risks

The cause-specific lifetime risks for the six most hazardous occupations (Table IV) indicate that there are causes of injury death that represent significant risks for specific occupations. Several of these high-risk causes of death for specific occupations have been reported in previous research: the risks associated with logging by Myers and Fosbroke [1994]; risks of fishing by Bender [1994]; and falls for structural metal workers by Suruda et al., [1995]. Being struck by falling objects has also been reported as a major cause of death for underground miners [Mine Safety and Health Administration, 1990], a major occupational segment of the Extractive Occupations group. The concept of lifetime risk, however, was not addressed in any of these works.

TABLE V. Lifetime Risk Estimates from Published Studies Identifying Occupational Exposures to Hazardous Substances

Authors	Population	Exposure	Working lifetime	Illness	Lifetime risk (deaths/ 1,000 workers)[a]
Nurminen et al., 1992	General exposed population	0.2 mg silica/m^3 [b]	40 Years	Silicosis	8.7
Palmer and Rickett 1992	Surgeons	18,000 operations w/pop. HIV rate = 0.0036%[b]	35 Years	HIV Infection	0.67
Stayner et al., 1992	Cadium Smelters	100 $\mu g/m^3$ Cadium Fumes[c]	45 Years	Lung Cancer	50–100
Thun et al., 1991	Cadium Smelters	200 $\mu g/m^3$-years Cadium Fumes[b]	45 Years	Lung Cancer	60
Smith and Stayner 1990	Miners	1.5 mg/m^3 Diesel Part.[d]	47 Years	Lung Cancer	15–30
Hodgson and Jones, 1990	Tin Miners	4 WLM/Year Radon[c]	40 Years	Lung Cancer	79
Friedberg, et al., 1989	Air Carrier Crewmembers	0.2–9.1 mSv/year Galactic Cosmic Radiation[e]	20 Years	Lung Cancer	0.1–5.0
Dong et al., 1988	Steelworkers	$>$2.50 mg/m^3 Coke Oven Emmissions[d]	40 Years	Lung Cancer	40
NIOSH 1987	Uranium Miners	4 WLM/Year Radon[c]	30 Years	Lung Cancer	35–40
		1 WLM/Year Radon	30 Years	Lung Cancer	5–10
Siegal, et al., 1983	Workers exposed to OSHA PEL	3 ppm Formaldehyde[c]	Unknown	Cancer	6.2

[a]Lifetime risk is expressed as deaths/1,000 workers.
[b]Medium exposure level.
[c]Regulatory standard exposure level.
[d]High exposure level.
[e]High risk coefficient.

The fatal injury risks presented in Table IV are comparable with lifetime risk estimates from studies for occupational exposures that result in such health outcomes as cancer or HIV infection shown in Table V. The lifetime risk of 36 deaths/1,000 lifetime workers for timber cutting and logging occupations due to being struck by falling objects is approximately the same risk identified for lung cancer among uranium miners exposed to ionizing radiation [NIOSH, 1987], and among workers exposed to cadmium fumes [Stayner et al., 1992; Thun et al., 1991]. The risk of airplane pilots dying from aviation accidents other than landings or take-offs (21.1 deaths/1,000 lifetime workers) is also similar to the lung cancer risk of uranium miners.

The remaining lifetime risks presented in Table IV, ranging from 1 to 14 deaths per 1,000 lifetime workers, are all comparable to lifetime risk estimates for cancer-causing occupational exposures such as formaldehyde [Siegel et al., 1983], diesel exhausts [Smith and Stayner, 1990], silica [Nurminen et al., 1992], galactic radiation [Friedberg et al., 1989], and coke oven emissions [Dong et al., 1988]. This suggests that specific injury events are as great a fatal hazard to certain occupations as cancer-causing exposures are for others.

The lifetime risks presented here are simplistic, using industry and occupation as surrogates for exposure, rather than accounting for exact exposure times to injury-causing events. Unlike occupational illness risk assessment studies, where exposures are well defined but outcomes are unclear, the relationship of the death to the work-related activity is clear but the worker's exposure is undefined. Injuries are acute events associated with the transfer of hazardous levels of energy. A fatality only occurs when the energy source contacts the worker in a specific way (e.g., a tree falling on a logger's leg may cause a severe fracture, but probably not death, while the same tree striking the logger's head will usually cause death). Since the worker is only exposed to a potential fatal injury hazard for a portion of the workday, the estimation of exposure for traumatic injuries is complex and require data that do not currently exist at the national level.

Better risk assessment of fatal injuries will require the development of new hazard-surveillance models that take into account a worker's exposure to fatal levels of energy [Griefe et al., 1995]. If such systems are developed, then risk assessment may be extended to the actual evaluation of job-specific tasks, and to the development of appropriate injury-prevention strategies.

CONCLUSIONS

Previous studies have identified worker populations having elevated annual fatal-injury rates. Generally, these

studies have been limited to identifying relatively heterogenous groups (e.g., construction workers, precision production, craft and repair workers) that account for a large proportion of fatalities, or that have a high annual fatality rate. Even in studies which have reported annual fatality rates of detailed industries and occupations, rates have not been provided to allow comparison of risk among different occupations by cause of death. Using Bureau of Census industry and occupation categories as a surrogate for exposure, this study identifies more specific worker populations at risk of fatal occupational injury. In order to facilitate comparison of cause-specific injuries with occupational disease risks, fatal-injury rates are presented in terms of working lifetime risk.

The use of lifetime risk to define traumatic injury hazards is a concept that has not been widely examined by safety professionals or injury-control researchers. The results of this paper suggest that when lifetime risk is considered for traumatic injuries, the risks for specific causes of death for certain occupations are of the same magnitude as impermissible cancer risks identified for specific occupational exposures. Therefore, risk assessment for traumatic causes of death should be considered equally with risk assessments for illness-causing exposures.

If prevention activities (e.g., training, regulation, administrative and engineering controls) are to focus on the most important fatal-injury problems, more emphasis must be placed on conducting hazard surveillance and developing exposure surveillance systems for traumatic-injury events. Such information will allow for the development of more complex lifetime risk models for traumatic injuries and better risk assessment of the hazards associated with occupation-specific work tasks.

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