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Expanded Analysis of Injury Mortality Among Unionized Construction Workers

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Background *To evaluate the utility of expanding the number and precision of injury categories used in previous occupational mortality studies, this study reanalyzed data from four previous studies of unionized construction workers (construction laborers, ironworkers, sheet metal workers, and operating engineers), by expanding the number of injury categories from 6 to 33.*

Methods *Proportionate mortality ratios (PMRs) were computed using the distribution of deaths from the National Occupational Mortality Surveillance System, a mortality surveillance system from 28 states, as a comparison. A blue collar comparison group was also used in additional analyses to adjust for socioeconomic and other factors.*

Results *This reanalysis identified significantly elevated PMRs in at least one of the four worker groups for falls, motor vehicle crashes, machinery incidents, electrocutions, being struck by falling objects, being struck by flying objects, explosions, suffocation, and water transport incidents. Limiting the comparison population to deaths among blue collar workers did not change the results substantially.*

Conclusion *This study demonstrates that increasing the precision of categories of death from injury routinely used in mortality studies will provide improved information to guide prevention.* Am. J. Ind. Med. 37:364–373, 2000. *Published 2000 Wiley-Liss, Inc.*†

KEY WORDS: construction; proportionate mortality ratio; fatal injury; occupation; epidemiology

INTRODUCTION

Epidemiologists conducting mortality studies routinely combine large numbers of specific causes of death into a smaller number of major groupings. For example, in the latest version of the National Institute for Occupational Safety and Health (NIOSH) Life Table Analysis System (LTAS) [Steenland et al., 1998], there were 99 categories used to describe all illness and injury mortalities. Only 6 of the 99 categories are used to describe injury mortality. These are transportation injuries, poisoning, suicides, homicides, falls, and other injuries. Each category of injury contains a diverse array of specific external causes of injury and poisoning codes (E-codes) of the International Classification of Diseases 9th revision (ICD-9) [WHO, 1977]. For example, the specific E-code for electrocution (E-925) is subsumed in a larger grouping called ''other injuries.'' Thus, a mortality study using the limited number of standard injury categories may not detect an increase in electrocutions, which is a leading cause of death in the construction industry [Kisner and Fosbroke, 1994].

To evaluate the utility of expanding the number and precision of injury categories used in occupational mortality

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studies, and to more fully describe the mortality experience of construction workers previously studied, we reanalyzed data from four studies of unionized construction workers by expanding the number of injury categories from 6 to 33. A blue collar comparison group was used in additional analyses to adjust for potential confounding factors due to the healthy worker effect, socioeconomic status, and lifestyle factors.

MATERIALS AND METHODS

Study Populations

The four studies used in this reanalysis include: (1) construction ironworkers of the International Association of Bridge, Structural, and Ornamental Ironworkers (IUBSOI) [Stern et al., 1997a]; (2) construction laborers of the Laborers' International Union of North America (LIUNA) [Stern et al., 1995]; (3) construction sheet metal workers of the Sheet Metal Workers International Association (SMWIA) [Alterman et al., 1996]; and (4) construction operating engineers of the International Union of Operating Engineers (IUOE) [Stern et al., 1997b]. The study selection criteria for all four study populations were those who had been active dues-paying members of one of the four unions for at least one continuous year and who had died in the United States. The study periods for each worker group are: (1) 1984-1991 for ironworkers; (2) 1985-1988 for construction laborers; (3) 1980-1991 for sheet metal workers; and (4) 1988-1993 for operating engineers.

The approximate membership of the four labor organizations were: (1) LIUNA, 423,000 (1989); (2) IUBSOI, 123,000 (1994); (3) IUOE, 375,000; and (4) SMWIA, 100,000. More details on the study populations and the duties they perform are published in the previous studies [Stern et al., 1995, 1997a,b; Alterman et al., 1996]. Overall, 18.6% of all construction workers were members of unions in the United States according to the 1997 Current Population Survey, but proportions of union members in a specific construction trade are unknown.

In this study, union members were identified from death beneficiary and membership files maintained at the national unions. The National Death Index and Social Security tapes were also searched to identify those deceased for whom a death benefit claim had not been filed by the beneficiary. In most cases, the unions provided a copy of the death certificate of a deceased member. For those death certificates that were not provided by the unions, copies were obtained from the Vital Statistical Office of the state where the member had died. Information retrieved from these files and death certificates included name, social security number, date of birth, race, gender, years of active dues-paying status, year of entry into the union, and local unions worked in. Information coded from death certificates included underlying cause of death and up to three contributory causes of death. All death certificates were coded by experienced nosologists according to the ICD-9 codes [WHO, 1977].

The proportionate mortality ratios (PMRs) in the previous studies were calculated with the NIOSH Life Table Analysis System (LTAS) which uses the U.S. population as a reference [Waxweiler et al., 1980; Steenland et al., 1990]. For this study, gender and age adjusted PMRs were calculated with the Proportionate Mortality Ratio Analysis System (PMRAS) [Dubrow et al., 1986] because of its flexibility for categorization of causes of death. The PMRAS uses deaths from the National Occupational Mortality Surveillance (NOMS) System along with the union members of interest as a reference population. For example, deaths from the NOMS along with members of the Ironworkers' union were used as a referent population for calculating PMRs for ironworkers. NOMS is a collaborative project among NIOSH, the National Center for Health Statistics, the National Cancer Institute, and selected state health departments which augments the mortality vital statistics system with coded industry and occupation data. Twenty-eight states provided death certificate data coded for industry and occupation for two or more years during 1980–1993 [Chen et al., 1997]. These included Alaska, California, Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Utah, Vermont, Washington, West Virginia, and Wisconsin. The information on the usual industry and occupation of the decedent during his or her life time is provided for the death certificate by the next-of-kin and coded according to the 1980 U.S. Census codes [Bureau of the Census, 1982], which makes it possible to use various occupational groups for comparison. From 1980–1993, there were 7,240,105 deaths in NOMS. Approximately 2 million of these deaths were of blue collar workers as identified by the United States Bureau of Census Occupational Codes 503–889 [Bureau of the Census, 1982] and included precision craft workers, operators, and laborers.

To address the difference in referent populations used by LTAS and PMRAS, we compared the PMRs computed by LTAS with the PMRs computed by PMRAS for operating engineers. The results are similar (Table I), suggesting that NOMS provides a representative sample of the U.S. population.

Statistical Analysis

An ICD-9 E-code rubric for cause of death categories used in the NIOSH National Traumatic Occupational Fatalities (NTOF) Surveillance System [Jenkins et al.,

TABLE I. Comparisons of the PMRs Computed by LTAS with PMRs Computed by PMRAS among International Union of Operating Engineers Members who Died from 1984 to 1993

Injury categories (E-codes)	LTAS[a] PMRs (95%CI)	PMRAS[b] PMRs (95%CI)
Transportation injuries (E800–848)	1.05 (0.88–1.24)	1.10 (0.93–1.30)
Poisoning (E850–869)	0.87 (0.45–1.52)	0.85 (0.44–1.48)
Suicides (E950–959)	1.22 (1.06–1.40)	1.32 (1.14–1.51)
Homicides (E960–978)	0.61 (0.36–0.96)	0.57 (0.34–0.90)
Falls (E880–888)	0.71 (0.53–0.91)	0.72 (0.54–0.93)
Other injuries (E890–928)	1.43 (1.20–1.70)	1.25 (1.05–1.49)

[a]LTAS: NIOSH Life Table Analysis System which uses the U.S. population as referent population.
[b]PMRAS: NIOSH Proportionate Mortality Ratio Analysis System which uses mortality data from 28 states as referent population.

1993] were used in this reanalysis. The six injury categories used in the previous studies (Table I) were expanded into 33 (Tables III–VI).

PMRs were based on the underlying cause of death and calculated by comparing the proportion of deaths from a specific cause within a specified occupation group with the proportion of deaths due to that cause among referent population decedents. PMRs were computed after stratification for age (18–64 years, and 65 years or older). If the observed number of deaths were 10 or less, 95% confidence intervals (95% CIs) were calculated based on an exact Poisson distribution [Bailar and Ederer, 1964]; otherwise, the Mantel-Haenszel χ^2 analysis was used, based on an approximation [Kang et al., 1997; Mantel and Haenszel, 1959]. PMRs were first computed using the entire population as a referent group and then repeated using blue collar workers as a referent group to adjust for potential confounding factors due to blue collar worker status.

RESULTS

The study populations consisted of: (1) 13,224 ironworkers; (2) 11,683 construction laborers; (3) 14,496 sheet metal workers; and (4) 15,842 operating engineers. The age-at-death range of operating engineers was 33 years and older, while the ranges of the other three groups were 18 years and older. Among operating engineers, only five deaths occurred under the age of 40 (Table II).

Cause-Specific Injury Mortality by Occupation

Tables III-VI present number of deaths, PMRs, and 95% CIs by age-at-death and by cause of death. Ironworkers, construction laborers, and sheet metal workers experienced a significantly elevated PMR for overall injuries (from E800 to E999). Ironworkers had the highest PMR for overall injuries (PMR = 144, 95% CI = 138–150), followed by construction laborers (PMR = 129, 95% CI = 124–134), and sheet metal workers (PMR = 122, 95% CI = 117–127). For operating engineers, deaths from overall injuries were elevated 12%, but it was not statistically significant.

Cause-specific excess injury mortality varied by occupation. The most prominent excess mortalities observed were for falls (PMR = 878, 95% CI = 763–1004) and being struck by flying objects (PMR = 737, 95% CI = 421–1197) among ironworkers; falls (PMR = 316, 95% CI = 259–381) and unspecified traffic-related motor vehicle incidents (PMR = 245, 95%CI = 209–286) among sheet metal workers; and machine-related incidents (PMR = 654, 95% CI = 442–934) among operating engineers. Construction

TABLE II. Demographic Characteristics of Unionized Construction Workers

	Construction laborers	Operating engineers	Sheet metal workers	Iron workers
Study years	1985–1988	1988–1993	1980–1991	1984–1991
Number of deaths	11,683	15,842	14,496	13,224
Male	11,624	15,842	14,416	13,203
Female	59	0	80	21
Mean age-at-death for all deaths (range)	67(18–102)	73(33–102)	66(18–103)	68(18–105)
Mean age-at-death for injury deaths	44	68	44	48

TABLE III. Injury Mortality among International Association of Bridge, Structure, and Ornamental Ironworker Members who Died from 1984 to 1991 by Age-at-Death Group

	18–64 years				65 years and older			
Causes of death	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**
All causes of death (E001–999)	4200	100	100		9024	100	100	
All illness (E001–799)	3188	91[f]	93[f]	90–92	8769	100	100	100–100
All injury (E800–999)	1012	144[f]	132[f]	138–150	255	105	110	92–119
Railway transport (E800–807)	2	52	39	6–187	0			
Motor vehicles (E810–829, 846–848)	286	132[f]	115[e]	118–149	52	109	118	82–143
MV traffic (E810–819)	275	131[f]	113[e]	116–147	48	104	112	77–138
occupants(E810–819/0.0, 0.1)	110	96	85	79–115	20	80	90	49–123
pedestrian (E810–819/0.7)	22	84	75	52–127	6	63	61	23–137
unspecified (E810–919/0.9)	99	202[f]	169[f]	165–246	21	199[f]	210[f]	123–304
MV non-traffic (E820–825)	10	215[e]	171	103–396	2	163	211	20–587
Water transport (E830–838)	8	128	119	55–251	1	102	132	3–571
Air transport (E840–845)	6	86	198	32–188	1	218	409	5–1214
Poisoning (E850–869)	35	105	94	73–145	5	97	98	32–227
Falls (E880–888)	211	878[f]	761[f]	763–1004	45	98	102	72–131
stairs or steps (E880)	5	142	134	46–332	4	67	64	18–171
ladders or scaffolding (E881)	22	941[f]	694[f]	590–1424	3	171	164	35–501
building or structure (E882)	100	2510[f]	1809[f]	2043–3053	6	430[f]	403[f]	158–936
into hole (E883)	9	1504[f]	1137[f]	688–2855	0			
one level to another (E884)	46	1169[f]	1026[f]	856–1560	5	158	149	51–369
to same level (E885–886)	2	210	264	25–758	4	99	99	27–253
unspecified falls (E887–888)	28	308[f]	296[f]	205–445	25	80	85	52–118
Fire (E890–899)	9	50[e]	43[f]	23–955	8	79	77	34–155
in private dwelling (E890, 895)	7	47[e]	41[f]	19–97	6	77	76	28–168
other places(E891–894, 896–899)	2	63	56	8–229	2	84	79	10–303
Nature / environment (E900–909)	8	107	114	46–212	3	54	55	11–157
Drowning (E910)	14	90	85	49–151	4	151	171	41–385
Suffocation E(911–913)	7	64	69	26–133	14	97	99	53–162
Struck by falling objects (E916)	31	377[f]	319[f]	256–535	2	128	139	19–464
Struck by flying objects (E917–918)	16	737[f]	577[f]	421–1197	0			
Machine (E919)	37	362[f]	308[f]	255–499	3	73	121	15–215
Explosion (E921, 923)	5	239	172	78–558	1	209	181	5–1163
Electrocution (E925)	15	249[f]	173	139–411	1	283	319	7–1575
Suicide (E950–959)	183	95	98	82–110	77	116	119	92–145
Homicide (E960–969)	91	92	82	74–113	11	130	130	65–233
Intent undetermined (E980–989)	15	99	102	56–164	1	42	44	1–232
Other incidents[d]	33	127	118	88–179	26	101	105	66–148

[a]PMRs were computed using the entire population as a comparison.
[b]PMRs were computed using blue collar workers as a comparison.
[c]95% Confidence interval for PMRs which were computed using all population as comparison.
[d]Other incidents include E870–E879, E914, E915, E920, E922, E924, E926, E927, E929, E930–E949, E970–E978, E990–E999.
[e]$P < 0.05$.
[f]$P < 0.01$.

laborers had elevated PMRs for 15 of the 19 major injury categories, with 10 categories being statistically significant (Table IV). A comparison of statistically significantly elevated injury mortality by cause of death and worker group is presented in Table VII.

Characteristics of injury mortalities within the same cause of death also varied by occupation. Although all four worker groups had an elevated PMR for motor vehicle crashes, only construction laborers had a significantly elevated PMR for traffic-related deaths involving

TABLE IV. Injury Mortality Among Laborers' International Union of North America Members who Died from 1985 to 1988 by Age-at-Death Group

	18–64 years old				65 years or older			
Causes of death	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**
All causes of death (E001–999)	4426	100	100		7257	100	100	
All illness (E001–799)	3364	93[f]	95[f]	92–95	7070	100	100	100–100
All injury (E800–999)	1062	129[f]	119[f]	124–134	187	96	99	83–111
Railway transport (E800–807)	8	199	149	86–393	1	387	394	10–2155
Motor vehicles (E810–829, 846–848)	375	138[f]	120[f]	124–153	47	125	134	92–167
MV traffic (E810–819)	366	138[f]	121[f]	124–153	46	127	135	93–169
occupants (E810–819/0.0, 0.1)	152	107	95	90–125	24	125	139	80–186
pedestrian (E810–819/0.7)	58	186[f]	170[f]	141–240	14	178	171	98–299
unspecified (E810–919/0.9)	104	162[f]	136[f]	132–196	7	81	87	33–168
MV non-traffic (E820–825)	7	126	102	51–259	0			
Water transport (E830–838)	13	165	156	88–282	0			
Air transport (E840–845)	2	24[e]	57	3.0–88	0			
Poisoning (E850–869)	47	131	118	96–174	3	73	74	15–212
Falls (E880–888)	62	243[f]	216[f]	187–312	23	63[e]	64[e]	40–94
stairs or steps (E880)	0				4	83	78	23–214
ladders or scaffolding (E881)	10	383[f]	288[f]	183–704	1	75	69	2–419
building or structure (E882)	13	311[f]	242[f]	166–532	0			
into hole (E883)	4	508[e]	409[e]	138–1300	0			
one level to another (E884)	17	401[f]	375[f]	233–641	2	86	79	10–309
to same level (E885–886)	1	94	115	2–521	0			
unspecified falls (E887–888)	17	178[e]	167	104–285	16	63	66	36–102
Fire (E890–899)	16	76	66	43–123	15	168	160	94–276
in private dwelling (E890, 895)	11	63	55[e]	32–113	14	206[e]	201[e]	112–345
other places(E891–894, 896–899)	5	134	120	44–313	1	47	42	1–260
Nature / environment (E900–909)	3	36	39	7–106	8	163	164	70–322
Drowning (E910)	26	134	126	88–197	0			
Suffocation (E911–913)	25	204[f]	209[f]	132–301	9	75	76	34–143
Struck by falling objects (E916)	28	305[f]	257[f]	203–441	1	81	90	2–452
Struck by flying objects (E917–918)	8	341[f]	269[e]	147–671	3	702[e]	860[e]	145–2051
Machine (E919)	44	377[f]	323[f]	274–505	1	32	56	1–178
Explosion (E921, 923)	7	306[e]	235	123–631	0			
Electrocution (E925)	15[e]	197[e]	142	111–326	0			
Suicide (E950–959)	175	81[e]	83[e]	69–94	41	78	80	56–106
Homicide (E960–969)	141	124[e]	112	105–146	14	198[e]	192[e]	108–333
Intent undetermined (E980–989)	29	161[e]	169[e]	108–231	2	96	100	12–348
Other incidents[d]	38	126	116	89–173	19	91	93	55–141

[a]PMRs were computed using the entire population as a comparison.
[b]PMRs were computed using blue collar workers as a comparison.
[c]95% Confidence interval for PMRs which were computed using all population as comparison.
[d]Other incidents include E870–E879, E914, E915, E920, E922, E924, E926, E927, E929, E930–E949, E970–E978, E990–E999.
[e]$P < 0.05$.
[f]$P < 0.01$.

pedestrians which requires further investigation to determine if it reflects their being struck while working at highway construction sites. In contrast, and for unknown reasons, sheet metal workers had a significantly elevated PMR for traffic-related deaths involving occupants; and only operating engineers and ironworkers had a significantly elevated PMR for non-traffic-related incidents. Ironworkers, construction laborers, and sheet metal workers, all experienced a significantly elevated PMR for falls. Within the category of falls, ironworkers experienced the highest PMR for falls from building and structure (PMR = 2510, 95% CI = 2043–3053); sheet

TABLE V. Injury Mortality among Sheet Metal Workers International Association Members who Died from 1980 to 1991 by Age-at-Death Group

	18–64 years old				64 years or older			
Causes of death	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**
All causes of death (E001–999)	5981	100	100		8515	100	100	
All illness (E001–799)	4815	96[f]	97[f]	95–97	8313	100	100	100–101
All injury (E800–999)	1166	122[f]	114[f]	117–127	202	89	93	77–102
Railway transport (E800–807)	0				0			
Motor vehicles (E810–829, 846–848)	421	143[f]	125[f]	130–164	40	89	97	64–122
MV traffic (E810–819)	412	144[f]	126[f]	130–158	39	90	97	64–123
occupants (E810–819/0.0, 0.1)	181	117[e]	105	101–136	13	56[e]	63	30–95
pedestrian (E810–819/0.7)	20	54[f]	50[f]	33–84	11	121	117	60–216
unspecified (E810–919/0.9)	164	245[f]	206[f]	209–286	14	141	150	77–237
MV non-traffic (E820–825)	8	124	101	53–244	1	87	107	2–484
Water transport (E830–838)	21	247[f]	229[f]	153–378	1	98	118	2–544
Air transport (E840–845)	12	114	254[f]	59–199	1	215	416	5–1197
Poisoning (E850–869)	40	90	82	65–123	4	83	84	23–213
Falls (E880–888)	108	316[f]	284[f]	259–381	43	102	105	74–137
stairs or steps (E880)	6	117	111	43–354	7	119	113	48–245
ladders or scaffolding (E881)	22	656[f]	480[f]	411–993	2	116	109	14–418
building or structure (E882)	31	613[f]	466[f]	417–870	3	222	210	46–648
into hole (E883)	1	124	100	3–690	0			
one level to another (E884)	17	323[f]	297	188–518	2	69	65	8–250
to same level (E885–886)	3	213	260	44–621	1	27	28	1–152
unspecified falls (E887–888)	29	211[f]	207[f]	142–304	29	102	109	68–147
Fire (E890–899)	19	79	69	47–126	7	73	70	29–149
in private dwelling (E890, 895)	16	81	71	46–131	4	54	53	15–139
other places (E891–894, 896–899)	3	69	62	14–202	3	133	124	27–387
Nature / environment (E900–909)	7	71	75	28–146	1	19	20	0–106
Drowning (E910)	26	120	116	78–176	2	78	88	9–282
Suffocation (E911–913)	12	78	84	40–137	10	74	76	36–137
Struck by falling objects (E916)	9	86	73	39–164	2	131	140	16–473
Struck by flying objects (E917–918)	3	103	81	21–302	0			
Machine (E919)	15	114	98	64–187	2	52	84	6–188
Explosion (E921, 923)	4	139	101	38–356	1	221	187	6–1231
Electrocution (E925)	15	198[e]	138	111–326	1	290	325	7–1614
Suicide (E950–959)	288	112	114[e]	99–126	65	104	107	80–133
Homicide (E960–969)	119	87	79[f]	72–105	5	62	63	20–144
Intent undetermined (E980–989)	19	92	95	55–143	2	84	89	10–304
Other incidents[d]	28	80	75	53–115	15	62	65	35–103

[a]PMRs were computed using the entire population as a comparison.
[b]PMRs were computed using blue collar workers as a comparison.
[c]95% Confidence interval for PMRs which were computed using all population as comparison.
[d]Other incidents include E870–E879, E914, E915, E920, E922, E924, E926, E927, E929, E930–E949, E970–E978, E990–E999.
[e]$P < 0.05$.
[f]$P < 0.01$.

metal workers experienced the highest PMR for falls from ladders or scaffolding (PMR = 656, 95% CI = 411–993); and construction laborers workers experienced the highest PMR for falls from one level to another (PMR = 401, 95% CI = 233–641).

Most of the elevated PMRs for injuries demonstrated no significant excess among workers aged 65 years or older. However, elevated PMRs after age 65 were observed among the following exceptions: (1) operating engineers for air transport-related incidents, motor vehicle crashes involving

TABLE VI. Injury Mortalities among International Union of Operating Engineers Members who Died from 1988 to 1993 by Age-at-Death Group

	18–64 years old				65 years or older			
Causes of death	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**	**OBS**	**PMR[a]**	**PMR[b]**	**95% CI[c]**
All causes of death (E001–999)	2863	100	100		12979	100	100	
All illness (E001–799)	2645	99	99	98–100	12614	100	100	100–100
All injury (E800–999)	218	112	112	97–128	365	104	109	94–115
Railway transport (E800–807)	0				0			
Motor vehicles (E810–829, 846–848)	62	125	120	96–160	67	94	102	73–120
MV traffic (E810–819)	57	119	114	90–154	65	95	101	73–121
Occupants (E810–819/0.0, 0.1)	27	100	101	66–146	29	73	82	49–105
Pedestrian (E810–819/0.7)	8	99	93	43–196	9	70	68	32–133
Unspecified (E810–919/0.9)	21	198[f]	179[e]	123–303	27	181[f]	187[f]	119–263
MV non-traffic (E820–825)	5	342[b]	293	111–799	2	110	131	13–397
Water transport (E830–838)	2	120	126	15–435	1	76	91	2–425
Air transport (E840–845)	6	271	610[f]	99–590	4	461[e]	795[f]	126–1179
Poisoning (E850–869)	5	73	70	24–171	7	97	100	39–199
Falls (E880–888)	9	77	74	35–147	49	72[e]	76	53–95
stairs or steps (E880)	3	135	133	28–396	4	50	49	14–127
ladders or scaffolding (E881)	2	185	151	22–670	6	225	231	83–491
building or structure (E882)	0				1	56	56	1–310
into hole (E883)	1	613	580	15–3418	0			
one level to another (E884)	0				3	64	63	13–187
falls to same level (E885–886)	0				3	50	53	10–145
unspecified falls (E887–888)	3	58	58	12–171	33	69[e]	75	48–97
Fire (E890–899)	2	30	26[e]	4–109	10	78	79	37–143
in private dwelling (E890, 895)	2	37	33	5–135	7	70	71	28–145
other places (E891–894, 896–899)	0				3	103	111	21–301
Nature / environment (E900–909)	3	84	82	17–248	9	124	122	57–235
Drowning (E910)	4	113	116	31–289	5	130	139	42–302
Suffocation (E911–913)	3	64	67	13–187	14	69	70	38–116
Struck by falling objects (E916)	3	103	94	21–300	5	217	239	70–505
Struck by flying objects (E917–918)	1	148	132	4–823	1	196	235	5–1093
Machine (E919)	30	654[f]	627[f]	442–934	7	118	189	47–243
Explosion (E921, 923)	2	329	269	40–1189	0			
Electrocution (E925)	1	91	68	2–510	1	224	277	6–1246
Suicide (E950–959)	59	97	106	74–126	147	153[f]	156[f]	129–180
Homicide (E960–969)	10	52[e]	50[e]	25–95	8	69	68	30–135
Intent undetermined (E980–989)	2	59	61	7–213	2	70	76	8–252
Other incidents[d]	14	131	128	72–220	28	74	77	49–107

[a]PMRs were computed using the entire population as a comparison.
[b]PMRs were computed using blue collar workers as a comparison.
[c]95% Confidence interval for PMRs which were computed using all population as comparison.
[d]Other incidents include E870–E879, E914, E915, E920, E922, E924, E926, E927, E929, E930–E949, E970–E978, E990-E999.
[e]$P < 0.05$.
[f]$P < 0.01$.

unspecified persons, and suicide; (2) construction laborers for homicides, being struck by flying objects, and fire in private dwellings; and (3) ironworkers for falls from building or structure and motor vehicle crashes involving unspecified persons.

Blue Collar Comparison

Restricting the comparison population to blue collar workers did not change the results substantially. Most injury cause-specific PMRs decreased slightly with the

TABLE VII. Comparisons of Statistically Significantly Elevated Injury PMR[a] by Worker Group

Causes of death	Ironworkers	Construction laborers	Sheet metal workers	Operating engineers
All causes of injury (E800–999)	144[d]	129[d]	122[d]	
Railway transport (E800–807)				
Motor vehicles (E810–829, 846–848)	132[d]	138[d]	143[d]	
Water transport (E830–838)			247[d]	
Air transport (E840–845)				
Poisoning (E850–869)				
Falls (E880–888)	878[d]	243[d]	316[d]	
Fire (E890–899)				
Nature / environment (E900–909)				
Drowning (E910)				
Suffocation (E911–913)		204[d]		
Struck by falling objects (E916)	377[d]	305[d]		
Struck by flying objects (E917–918)	737[d]	341[d]		
Machine (E919)	362[d]	377[d]		654[d]
Explosion (E921, 923)		306[c]		
Electrocution (E925)	249[d]	197[c]	198[c]	
Suicide (E950–959)				
Homicide (E960–969)		124[c]		
Intent undetermined (E980–989)		161[c]		
Other incidents[b]				

[a]PMRs were computed for workers aged 64 years or younger and using all population as a comparison.
[b]Other incidents include E870–E879, E914, E915, E920, E922, E924, E926, E927, E929, E930–E949, E970–E978, E990–E999.
[c]$P < 0.05$.
[d]$P < 0.01$.

exception of a substantial increase for air transport incidents.

DISCUSSION

By using detailed injury categories, this study identified preventable causes of death that in previous studies were aggregated into larger categories. Significantly elevated PMRs were identified in at least one of the four worker groups for motor vehicle crashes, machinery incidents, electrocutions, being struck by falling objects, being struck by flying objects, explosions, suffocation, and water transport incidents. These specific causes of death were not identified in previous studies because they were aggregated into two large categories called ''other injuries'' and ''transportation injuries.''

The occupation and cause-specific mortality patterns identified in this study agree closely with the results from an NTOF study [Chen and Fosbroke, 1998] and point to specific safety hazards that are associated with a specified worker group. Operating engineers who were exposed to equipments such as cranes, bulldozers, and drilling machines suffered a greater than expected risk of death from machinery incidents. Ironworkers and sheet metal workers who were exposed to heights suffered increased risk of dying from falls. Construction laborers who were exposed to many of these hazards at construction sites experienced broader safety risks. A possible explanation for the excess of water transportation deaths among sheet metal workers is that a large number of sheet metal workers were employed in the ship building industry. A more detailed study, however, is still needed to determine the exact cause of death.

The observed elevated injury mortality persisted when using a blue collar comparison population, but were slightly less elevated. The rationale for using a blue collar comparison is to adjust for socioeconomic and other factors. Results from other studies and surveillance data examining occupational fatal injuries among construction workers are consistent with these results. In the California Occupational Mortality Study (COMS) [California DOH, 1987] which examined standardized mortality ratios (SMRs) for various occupations and the COMS II [Singleton and Beaumont, 1989] where results were adjusted for smoking, alcohol, and socioeconomic status, it was reported that white male construction laborers along with tile setters, carpet layers, drywall installers, glaziers, insulation workers, and structural metal workers had significantly elevated SMRs for falls and machine-related injuries, suicides, and all other injuries. Both the National Traumatic Occupational Fatal-

ities Surveillance (NTOF) and Census of Fatal Occupational Injuries (CFOI) reported construction as one of the most dangerous industries in the United States in terms of occupational fatal injuries [NIOSH, 1998; Pollack et al., 1996]. The NTOF study [Chen and Fosbroke, 1998] of work-related fatal injuries by occupation in the construction industry reports that structural metal workers (also known as ironworkers), operating engineers, construction laborers, and sheet metal workers have a work-related fatal injury rate higher than the average rate for the entire construction industry.

Excess injury deaths identified in this study included non-occupational components. The movement of elevated PMRs for homicides and electrocutions toward null when using blue collar comparisons suggests that some portion of this excess risk is non-occupational. The elevated PMRs for homicide and fire in private dwellings among construction laborers aged 65 years or older also suggests non-occupational risks. Living in a community with a high homicide rate might also present potential risks for homicide. Using a blue collar comparison can minimize the potential bias associated with certain sociodemographic factors. However, information on specific non-occupational risk factors was not available for this study.

Limitations of the Study

Limitations of union-based PMR studies have been well documented in previous studies [Stern et al., 1995, 1997a,b; Alterman et al., 1996]. Of particular concern is that the magnitude of the PMR for each cause of death is dependent on the magnitude of the PMR for other causes of death. Other limitations include potential inaccuracies in cause of death on the death certificates [Stern et al., 1995, 1997a,b], limited information on actual occupational exposure, and limited information on whether the injury was associated with work. These limitations need to be considered when interpreting results of this study.

Another limitation of this study is generalizing its results beyond unionized construction workers. This is illustrated by the results for operating engineers. Chen and Fosbroke [1997] reported that operating engineers had a work-related fatal injury rate of 41 deaths/100,000 workers, more than three times the average rate for all construction workers (12 deaths/100,000 workers), and had major problems related to machinery incidents, motor vehicle crashes, and being struck by falling objects. This study probably underestimated the true injury mortality among operating engineers because it was limited to union members only.

This study, nevertheless, has served two purposes. As a reanalysis, it provides richer information on injury mortality among unionized construction workers; and from a broader perspective, demonstrates the utility in expanding the routine categories of death that are used in mortality studies. We are currently developing categories of injury mortality for use in cohort mortality studies and, for purposes of comparison, calculating their rate of occurrence in the U.S. population in order to be able to more fully characterize occupational injury mortality in occupational cohorts.

REFERENCES

Alterman T, Salg JA, Lalich NR, Petersen MR, Robinson CF. 1996. Proportionate mortality study of sheet metal workers. Presentation at the 124th American Public Health Association Annual Meeting, New York, NY.

Bailar JC, Ederer F. 1964. Significant factors for the ratio of a Poisson variable to its expectation. Biometrics 20:639–643.

Bureau of the Census. 1982. 1980 Census of Population: Alphabetical index of industries and occupations—final edition. Washington, DC: U.S. Department of Commerce, publication no. PHC–R3.

California Department of Health. 1987. California occupational mortality (COM) 1979–1981. Sacramento, CA: California Department of Health, Health Demographics Section.

Chen G, Burnet CA, Cameron L, Alterman T, Lalich NR, Tanaka S, Althouse R. 1997. Tuberculosis mortality and silica exposure: A case-control study based on a national mortality database for the years 1983–1992. Int J Occup Environ Health 3:163–170.

Chen G, Fosbroke DE. 1998. Work-related fatal injury risks of construction workers by occupation and cause of death. Human Ecolog Risk Assess 4:1371–1390.

Debrow R, Spaeth S, Burnett CA, Adams S, Petersen M, Robinson CF. 1993. Proportionate Mortality Ratio Analysis System—Version V. Draft Documentation. Cincinnati, OH: National Institute for Occupational Safety and Health (NIOSH).

Jenkins EL, Kisner SM, Fosbroke DE, Layne LA, Stout NA, Castillo DN, Cutlip PM, Cianfrocco R. 1993. Fatal injuries to workers in the United States, 1980–1989: A decade of surveillance. Cincinnati, OH: DHSS [NIOSH] publication number 93–108.

Kang SK, Burnett CA, Freund E, Walker J, Lalich NR, Sestito J. 1997. Gastrointestinal cancer mortality of workers in occupations with high asbestos exposure. Am J Ind Med 31:713–718.

Kisner SM, Fosbroke DE. 1994. Injury hazards in the construction industry. J Occup Med 36:137–143.

Mantel N, Haenszel W. 1959. Statistic aspects of the analysis of data from retrospective studies of disease. J Natl Cancer Inst 22: 719–748.

National Institute for Occupational Safety and Health (NIOSH). 1998. Fatal Occupational Injuries—United States, 1980–1994. MMWR 47:297–302.

Pollack ES, Griffin M, Ringen K, Weeks JL. 1996. Fatalities in the construction industry in the United States, 1992–1993. Am J Ind Med 30:325–330.

Singleton JA, Beaumont JJ. 1989. COMS II: California Occupational Mortality, 1979–1981. Sacramento, CA: California Department of Health, Health Demographics Section.

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

Steenland K, Spaeth S, Cassinelli R, Laber P, Chang L, Kock K. 1998. NIOSH life table program for personal computers. Am J Ind Med 34:517–518.

Stern F, Schulte P, Sweeney MH, Fingerhut M, Vossenas P, Burkhardt G, Kornak MF. 1995. Proportionate mortality among construction laborers. Am J Ind Med 27:485–509.

Stern FB, Sweeney MH, Ward E. 1997a. Proportionate mortality among unionized construction ironworkers. Am J Ind Med 31: 176–187.

Stern F, Haring-Sweeney M. 1997b. Proportionate mortality among unionized construction operating engineers. Am J Ind Med 32:51–65.

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 25:115–124.

World Health Organization. 1977. International classification of diseases: Manual of the international statistical classification of diseases, injuries, and causes of death. Geneva, Switzerland: WHO.