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Mortality Among North Carolina Construction Workers, 1988–1994

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This study evaluated proportionate mortality patterns among all male construction workers in North Carolina who resided and died in North Carolina during the period 1988–1994. Proportionate Mortality Ratios (PMRs) and Proportionate Cancer Mortality Ratios (PCMRs) compared the number of deaths among male construction workers with the number of deaths expected based on the gender, race, and cause-specific mortality experience of the entire North Carolina population by five-year age groups for the same years of study. PMRs based on United States death rates also were calculated. Among all male construction workers, significantly elevated mortality was observed for several causes possibly related to work including malignant neoplasms of buccal cavity (PMR = 143), pharynx (PMR = 134), and lung (PMR = 113), pneumoconiosis (PMR = 111), transportation accidents (PMR = 106), and accidental falls (PMR = 132). Elevated mortality also was observed for causes more related to lifestyle and non-occupational factors including alcoholism (PMR = 145), cirrhosis of the liver (PMR = 129), accidental poisoning (PMR = 136), and homicide (PMR = 141). Patterns of elevated mortality for Whites and Black men were similar and PCMR mortality patterns for Blacks and Whites combined were similar to PMRs. Construction workers were at significantly increased risk for deaths resulting from falls from ladders or scaffolds, falls from or out of buildings or structures, and electrocutions. Construction trades found to have statistically elevated cancer risks include laborers and roofers (buccal cavity), painters (pharynx), laborers (peritoneum), and carpenters, painters, brick masons, and operating engineers (lung). These data are consistent with other reports demonstrating excess mortality from asbestos-related diseases (pneumoconiosis, lung cancer, and mesothelioma) among construction workers. Drywall workers and laborers were found to have a statistically elevated risk of death as a result of respiratory tuberculosis.

Keywords Asbestos, Construction, Construction Trades, Proportionate Cancer Mortality Ratio, Proportionate Mortality Ratio

Construction is one of the largest industries in the United States employing 5 to 6 percent of the labor force.[1] It is also one of the most dangerous industries, accounting for 15 percent of all occupational fatalities. The average annual occupational fatality rate for North Carolina construction workers for the period 1980–1989 was 27.0 deaths per 100,000 workers compared to the U.S. rate of 25.61 cases per 100,000 workers.[2] Construction trades, as defined by Standard Industrial Classification (SIC) codes 15, 16, and 17, have a much higher rate of filing workers' compensation claims than the general U.S. workforce. A lost-time workers' compensation claim rate of 4.91 per 100 full-time workers was reported among construction workers for the year 1993 compared to an overall rate of 2.86 per 100 full-time workers.[3] Injury and illness rates for North Carolina construction workers are comparable.[4] In addition to elevated risks for fatalities and non-fatal injuries, construction workers are at increased risk of occupational diseases resulting from exposure to numerous substances including silica, asbestos, inorganic lead, solvents, carbon monoxide, and other mineral dusts.[5]

Despite health and safety risks experienced by construction workers and the growing concerns over the costs associated with chronic diseases, work-related injuries, and illnesses and fatalities among these workers, few studies have examined the general health and mortality of this workforce. Episodic employment, changing and unpredictable work sites, and rapid contractor turnover increase the risk of occupational injuries and present special difficulties in studying and controlling occupational health hazards in construction.[6] This study evaluated proportionate mortality patterns of male construction workers

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TABLE I
North Carolina construction worker mortality study worker categories by usual trade

Title of trade category	Occupational codes
Carpenters, Carpenter Apprentices, and Supervisors	567, 569, 554
Construction Laborers	869
Painters, Paperhangers, and Plasterers and Supervisors	579, 583, 584, 556
Brick Masons, Stonemasons, Tile Setters, Apprentices and Supervisors	563, 564, 565, 553
Electricians, Electrical Power Installers and Repairers, Apprentices and Supervisors	575, 576, 577, 555
Plumbers, Pipe Fitters, Steamfitters, Apprentices and Supervisors	585, 587, 557
Concrete and Terrazzo Finishers and Glaziers	588, 589
Mechanics and Repairers	503–549
Drywall Installers	573
Roofers	595
Insulators	593
Welders and Cutters	783
Operating Engineers and Heavy Equipment Operators	844 through 859
All Other Construction Craft Workers, NEC	566, 594, 596, 597, 598
Construction Supervisors, NEC	558
Construction Engineers, Managerial, Professional Speciality Occupations, Technical Sales and Administrative	005 through 389
All Other Construction-Related Occupations	All codes not listed above

who resided and died in North Carolina during the period 1988–1994, providing information on a largely non-unionized construction workforce in the southeastern United States. In addition to overall results, separate mortality analyses are reported by construction-related craft or trade.

MATERIALS AND METHODS

Data Sources

The North Carolina State Center for Health and Environmental Statistics participates in the National Institute for Occupational Safety and Health (NIOSH) surveillance program which codes "usual" occupation and industry on death certificates.[7] Coding of usual occupation and industry, provided on the death certificate by next of kin, was done by clerks trained in procedures developed by the Bureau of the Census for NIOSH and the National Center for Health Statistics.[8]

The current study used all deaths among males in North Carolina who both resided in and died in North Carolina during the period 1988–1994. Deaths among workers who usually worked in the construction industry were identified by census occupation code 060 (SIC codes 15, 16, or 17). Deaths among construction workers included 21,617 White males, 7,483 Black males, and 454 males of other races. Information on age, race, gender, usual occupation and industry, and underlying cause of death also were provided. The study was restricted to males because of the small number of deaths among females ($n = 474$), with usual industry identified as construction. Analyses of mortality by race were restricted to Whites and Blacks because of the small number of deaths among other race groups.

Identification of Construction Industry Workers and the Trades

Deaths among construction industry workers were grouped by trades for analyses of mortality stratified by usual construction occupation. Table I provides a detailed listing of occupational categories and codes for each trade. These code categories are very similar to those used by Robinson with the exception that supervisors in each trade were grouped with their respective trade rather than excluded from analyses.[7] This was based on the rationale that supervisors in the construction industry have normally worked in the trade for many years before being classified as a supervisor; therefore, their chronic occupational disease risks should be similar to trade workers.

Proportionate Mortality Analyses

A proportionate mortality study design was used to examine the mortality risk patterns of construction workers. The proportionate mortality ratio (PMR) compares an observed and expected number of deaths for important cause of death categories with expected deaths calculated by application of appropriate death proportions from the referent population.[9]

The current PMR study covered all deaths among construction workers residing in and dying in North Carolina between 1988–1994. Both overall proportionate mortality and proportionate cancer mortality ratio (PCMR) analyses were undertaken. Separate analyses were undertaken for all males, White males and Black males. The number of observed deaths by cause among males in the study population of construction workers was compared with the number of deaths expected based on the

gender, race, and cause-specific mortality experience of the entire North Carolina population by five-year age groups for the same years of study (1988–1994). PCMRs were calculated to partially control for possible "healthy worker effect" biases in cancer mortality.[5]

In addition to PMRs based on North Carolina death rates and proportions, further analyses were undertaken using United States death rates. Observed deaths among all North Carolina construction workers between 1988 and 1994 were compared to expected numbers calculated using gender, race, age (5-year age groups), and calendar time (5-year groups) cause-specific proportions for the U.S. A personal computer (PC) version of the NIOSH Lifetable Analysis System was used to assign deaths to 92 NIOSH death groups and to stratify deaths by race, gender, and calendar time.[10] A custom SAS routine was written using the export file from the NIOSH PC lifetable program to calculate the ratio of observed to expected deaths, or the proportionate mortality ratio (PMR).[11]

To partially account for latency for chronic occupational diseases such as some cancers, separate analyses were undertaken restricting deaths to those occurring among workers 65 years or older. Additional PMR analyses also were undertaken to examine further deaths caused by accidental falls and deaths resulting from external causes likely to be work-related. External cause of death categories designated as "usually work-related" were the same as defined by NIOSH using ICD-9 codes.[7,12]

The statistical significance of resulting PMRs was determined using a summary chi-square test with one degree of freedom.[13]

RESULTS

A summary of statistically significant PMRs for all male North Carolina construction workers (n = 29,554), White males (n = 21,617), and Black males (n = 7,483) for the period of 1988 to 1994 is shown in Table II. Only statistically significant ($p < 0.05$) categories with at least five observed deaths are included in Table II. The restriction to categories with at least five deaths is because of instability of PMRs based on fewer deaths and invalid chi-square tests with such small numbers.

PMR for Male Construction Workers for All Trades

For all male construction workers, significantly elevated PMRs were observed for malignant neoplasms (MN) of other parts of the buccal cavity (PMR = 143); MN of the pharynx (PMR = 134); MN of trachea, bronchus, and lung (PMR = 113); alcoholism (PMR = 145); pneumonoconiosis and other respiratory diseases (PMR = 111); cirrhosis of the liver (PMR = 129); transportation accidents (PMR = 106); accidental poisoning (PMR = 136); accidental falls (PMR = 132); other accidents not otherwise classified (PMR = 126); and homicide (PMR = 141). Results for White and Black male workers were similar in direction although not all categories were statistically significant for Black males because of the smaller number of deaths. Exceptions were White males who had a significant excess of MN of the larynx (PMR = 135) and Black males who had a significantly elevated PMR for MN of the esophagus (PMR = 136).

Several causes showed significantly decreased mortality risks. All male workers experienced deficits for MN of rectum, biliary passages and liver, neoplasms of lymphatic and hematopoietic tissues, diabetes mellitus, disorders of the nervous system and sense organs, diseases of the heart, cerebrovascular disease, asthma, certain diseases of the musculoskeletal system, and all other causes. Again, similar patterns of disease deficits were observed for Whites and Blacks.

PMR analyses using proportions of U.S. deaths for generation of expected deaths produced results very similar to those using North Carolina data. Using U.S. death rates, the risk for lung cancer was slightly larger (PMR = 125) as was the risk for pneumonoconiosis and other respiratory diseases (PMR = 122). Significantly reduced mortality risks were observed for cancers of the stomach (PMR = 71) and bladder (PMR = 74).

Table III provides a summary of PCMR results and comparisons with the PMR values for selected cancer sites. Results are shown for each site where any PMR was found to be statistically elevated or decreased. PCMR results, which adjust the PMR as a result of significant changes in nonmalignant causes of death, were very similar to the PMRs. For all male workers, PCMRs were slightly lower than PMRs for MN of other parts of the buccal cavity (PCMR = 141), MN of the pharynx (PCMR = 132), and MN of the trachea, bronchus, and respiratory system (PCMR = 111). For white male workers, PCMRs were lower than PMRs for MN of larynx (PCMR = 132), MN of pharynx (PCMR = 140), and MN of trachea, bronchus & respiratory system (PCMR = 113). For all black male workers, PCMRs were lower than PMRs for MN of other parts of buccal cavity (PCMR = 175) and MN of esophagus (PCMR = 129).

Results of more detailed analyses of deaths because of falls and deaths as a result of external causes usually related to work are shown in Tables IV and V, respectively. Construction workers were found to be at significantly increased risk for deaths resulting from falls from ladders or scaffolds (PMR = 224), falls from or out of buildings or structures (PMR = 266), and electrocutions (PMR = 229). Although not statistically significant, these workers also were found to be at increased risk of death as a result of being struck by falling objects, being caught in or between objects, accidents involving cutting or piercing objects, explosions of pressure vessels, and accidents caused by explosive material.

Deaths resulting from accidental poisonings (n = 237) were further reviewed. Based on ICD-9 classifications on death certificates, 135 (57%) of these deaths were because of drugs and 88 (37%) were because of alcohol. Motor vehicle exhausts or carbon monoxide accounted for an additional 10 (5%) of these deaths. A total of 1007 homicides occurred among this group, representing a statistically significant excess (PMR = 141). These deaths were largely a result of firearms use (71%) and stabbing (18%).

TABLE II

Summary of statistically significant categories of mortality ($p < 0.05$) among North Carolina construction workers, 1988–1994 (causes with five or more deaths) mortality by race for males

Cause of death	ICD-9 code	Obs death	PMR
A. All male workers, all trades			
Malignant neoplasms (MN) of buccal cavity and pharynx			
MN of other parts of buccal cavity	142–145	50	143
MN of pharynx	146–149	117	134
MN of digestive organs and peritoneum			
MN of intestine except rectum	152, 153	443	84
MN of biliary passages and liver	155.0, 155.1 156	81	78
MN of respiratory system			
MN of trachea, bronchus, and lung	162	3,023	113
MN of other and unspecified sites			
MN of brain and other parts of nervous system	191, 192	136	77
Neoplasms of lymphatic and hematopoietic tissue			
Lymphosarcoma and reticulosarcoma	200	12	56
Leukemia and aleukemia	204–208	197	81
Other neoplasms of lymphatic and hematopoietic tissue	202, 203	290	85
Diabetes mellitus	250	460	78
Mental psychoneurotic and personality disorder			
Alcoholism	303	304	145
Disorders of the nervous system and sense organs			
Other diseases of the nervous system and sense organs	320–337, 341–389	327	75
Diseases of the heart			
Rheumatic heart disease, including fever	390–398	31	65
Ischemic heart disease	410–414	6,303	95
Chronic disease of endocardium	424	103	77
Hypertension with heart disease	402, 404	252	86
Other diseases of the circulatory system			
Cerebrovascular disease	430–438	1,599	95
Diseases of the respiratory system			
Asthma	493	35	70
Pneumonoconiosis and other respiratory diseases	470–478 494–519	1,355	111
Diseases of the digestive system			
Cirrhosis of the liver	571	666	129
Disease of the musculoskeletal system and connective tissue			
Other diseases of the MS system	710, 717–719, 722–729, 731–739	22	61
Accidents			
Transportation accidents	E800–848, E929.0–929.1	1,450	106
Accidental poisoning	E850–869	237	136
Accidental falls	E880–888, E929.3	222	132
Other accidents	E890–928, E929.4–929.9	679	126
Violence			
Homicide	E960–978	1,007	141

(*continued on next page*)

TABLE II

Summary of statistically significant categories of mortality ($p < 0.05$) among North Carolina construction workers, 1988–1994 (causes with five or more deaths) mortality by race for males (*continued*)

Cause of death	ICD-9 code	Obs death	PMR
B. White male workers, all trades			
Malignant neoplasms (MN) of buccal cavity and pharynx			
MN of lip	146–149	76	141
MN of digestive organs and peritoneum			
MN of intestine except rectum	152, 153	331	81
MN of biliary passages and liver	155.0, 155.1, 156	58	75
MN of respiratory system			
MN of larynx	161	69	135
MN of trachea, bronchus, and lung	162	2,371	115
MN of other and unspecified sites			
MN of brain and other parts of nervous system	191, 192	123	78
Neoplasms of lymphatic and hematopoietic tissue			
Leukemia and aleukemia	204–208	161	82
Diabetes mellitus	250	302	79
Mental, psychoneurotic, and personality disorders			
Alcoholism	303	171	162
Disorders of the nervous system and sense organs			
Other diseases of the nervous system and sense organs	320–337, 341–389	250	71
Diseases of the heart			
Rheumatic heart disease, including fever	390–398	24	66
Ischemic heart disease	410–414	5,027	95
Chronic disease of endocardium	424	78	75
Hypertension with heart disease	402, 404	104	78
Diseases of the respiratory system			
Pneumonoconiosis and other respiratory diseases	470–478, 494–519	1,141	114
Diseases of the digestive system			
Cirrhosis of the liver	571	486	137
Accidents			
Transportation accidents	E800–848 E929.0–929.1	1,127	109
Accidental poisoning	E850–869	144	131
Accidental falls	E880–888, E929.3	172	130
Other accidents	E890–928 E929.4–929.9	457	127
Violence			
Homicide	E960–978	495	150
C. Black male workers, all trades			
Malignant neoplasms (MN) of buccal cavity and pharynx			
MN of other parts of buccal cavity	142–145	18	179
MN of digestive organs and peritoneum			
MN of esophagus	150	119	136

(Continued on next page)

TABLE II

Summary of statistically significant categories of mortality ($p < 0.05$) among North Carolina construction workers, 1988–1994 (causes with five or more deaths) mortality by race for males (*continued*)

Cause of death	ICD-9 code	Obs death	PMR
MN of respiratory system			
MN of trachea, bronchus, and lung	162	629	109
Neoplasms of lymphatic and hematopoietic tissue			
Leukemia and aleukemia	204–208	30	68
Other neoplasms of lymphatic and hematopoietic tissue	202, 203	48	69
Diabetes mellitus	250	144	75
Diseases of the blood & blood-forming organs			
Anemias of other and unspecified type	280 281.1–281.8, 282–285	12	55
Mental, psychoneurotic, and personality disorders			
Alcoholism	303	128	129
Diseases of the heart			
Ischemic heart disease	410–414	1,180	94
Other diseases of the circulatory system			
Hypertension without heart disease	401, 403, 405	41	70
Cerebrovascular disease	430–438	459	90
Accidents			
Accidental poisoning	E850–869	85	145
Accidental falls	E880–888, E929.3	45	135
Other accidents	E890–928 E929.4–929.9	206	124
Violence			
Homicide	E960–978	462	133

TABLE III

Comparison of PMR and PCMR results North Carolina construction workers, 1988–1994[a]

		All males		Whites		Blacks	
Cause of death	ICD-9 code	PMR	PCMR	PMR	PCMR	PMR	PCMR
Other parts of buccal cavity	142–145	143*	141*	128	126	179*	175*
Pharynx	146–149	134*	132*	141*	140*	122	118
Esophagus	150	104	102	83	83	136*	129*
Intestine except rectum	152, 153	84*	83*	81*	80*	95	91
Biliary passages and liver	155.0, 155.1, 156	78*	77*	75*	74*	89	87
Larynx	161	121	118	135*	132*	101	96
Trachea, bronchus, and lung	162	113*	111*	115*	113*	109*	103
Eye	190	137	136	98	95	1030*	960*
Brain and other parts of nervous system	191, 192	77*	80*	78*	81*	76	77
Lymphosarcoma and reticulosarcoma	200	56*	59*	60	63	36	37
Leukemia and aleukemia	204–208	81*	83*	82*	84*	68*	68*
Other hematopoietic cancers	202, 203	85*	84*	90	89	69*	67*

[a]Cancer sites listed where any PMR found to be statistically significant among all males, whites or blacks.

*$p < 0.05$.

TABLE IV
North Carolina construction worker mortality, 1986–1994
overall mortality from falls

Cause of death	ICD-9 code	Obs #	PMR
Fall on or from stairs or steps	E880	10	90
Fall on or from ladders or scaffolding	E881	24	224*
Fall from/out of building/structures	E882	36	266*
Fall into hole or opening in surface	E883	3	118
Other fall from one level to another	E884	23	108
Fall on same level from slipping, tripping, or stumbling	E885	2	68
Fall on same level from collision, pushing, shoving by or with another person	E886	0	—
Fracture, cause unspecified	E887	34	93
Other and unspecified fall	E888	84	124

*$p < 0.05$.

TABLE V
North Carolina construction worker mortality, 1986–1994
fatalities resulting from causes usually work-related, all male workers

Cause of death	ICD-9 code	Obs #	PMR
Accidents involving powered vehicles used solely within buildings/premises	E846	0	—
Struck by falling object	E916	43	124
Striking against or by objects or persons	E917	5	100
Caught in or between objects	E918	2	152
Accidents caused by machinery	E919	44	107
Accidents caused by cutting/piercing instruments or objects	E920	8	189
Accidents caused by explosion of pressure vessel	E921	4	168
Accidents caused by explosive material	E923	6	185
Accidents caused by hot substances or object, caustic or corrosive material and steam	E924	2	98
Accident caused by electric current	E925	55	229*
Accident caused by radiation	E926	0	—
Overexertion or strenuous movements	E927	0	—

*$p < 0.05$.

Analyses of mortality restricted to those 65 years and older produced results similar to those of the overall cohort. Cancers of other parts of the buccal cavity were increased (PMR = 138) as was mortality resulting from pneumoconiosis and other respiratory diseases (PMR = 107), although these were not statistically significant. All other excesses seen for the entire population were observed for those 65 and older. Interestingly, the risk of death because of accidental falls was slightly higher in the older cohort (PMR = 160), and the homicide risk was nearly equal to that observed among younger workers. As was observed in the overall population, a significant deficit in ischemic heart disease risk (PMR = 93) was seen in older workers.

Mortality among Construction Workers by Usual Trade

Mortality by trade was analyzed to identify groups of workers possibly at higher risk. The trade groups considered are listed in Table I. Following is a discussion of statistically significant results for each trade. Only causes with at least five observed deaths are presented.

Carpenters, Carpenters' Apprentices, and Supervisors

For carpenters, carpenters' apprentices, and supervisors, elevated PMRs were observed for MN of the trachea, bronchus, and lung (PMR = 119), alcoholism (PMR = 173), pneumonoconiosis and other respiratory diseases (PMR = 114), other diseases of male genital organs (PMR = 305), transportation accidents (PMR = 121), other accidents (PMR = 122), and homicide (PMR = 159). Significantly reduced mortality was observed for MN of intestines except rectum (PMR = 70).

Construction Laborers

Construction laborers had significantly elevated PMRs for respiratory tuberculosis (PMR = 189), MN of other parts of the buccal cavity (PMR = 245), MN of the esophagus (PMR = 137), MN of the peritoneum and unspecified digestive organs (PMR = 239), alcoholism (PMR = 153), other mental disorders (PMR = 138), penumonoconiosis and other respiratory diseases (PMR = 118), cirrhosis of the liver (PMR = 124), accidental falls (PMR = 147), other accidents (PMR = 131), and homicide (PMR = 148). Significantly decreased mortality was observed for ischemic heart disease (PMR = 93) and other neoplasms of lymphatic and hematopoietic tissue (ICD-9 codes 202–203, PMR = 71).

Painters, Paperhangers, Plasterers, and Supervisors

Painters, paperhangers, plasterers, and supervisors had significantly elevated PMRs for MN of the pharynx (PMR = 178), MN of the trachea, bronchus, and lung (PMR = 118), alcoholism (PMR = 212), pneumonia (PMR = 133), pneumonoconiosis and other respiratory disease (PMR = 152), cirrhosis of the liver (PMR = 155), accidental poisoning (PMR = 185), and homicide (PMR = 180). Significantly decreased mortality was observed for MN of the kidney (PMR = 39), brain (PMR = 31), intestine except rectum (PMR = 58), and leukemia (PMR = 45). Ischemic heart disease mortality also was significantly reduced (PMR = 87).

Brick Masons, Stonemasons, Tile Setters, Apprentices, and Supervisors

Brick masons, stonemasons, tile setters, apprentices, and supervisors experienced significantly elevated PMRs for MN of

larynx (PMR = 199), MN of the trachea, bronchus, and lung (PMR = 118), diseases of the arteries, veins, and pulmonary circulation (PMR = 137), cirrhosis of the liver (PMR = 140), accidental falls (PMR = 190), and homicide (PMR = 130).

Electricians, Power Installers and Repairers, Apprentices, and Supervisors

Significantly elevated PMRs were observed among electricians, electrical power installers and repairers, apprentices and supervisors for MN of the stomach (PMR = 189), alcoholism (PMR = 181), cirrhosis of the liver (PMR = 154), transportation accidents (PMR = 126), and other accidents (PMR = 162). Deficits of ischemic heart disease (PMR = 88) and homicide (PMR = 58) were observed for electricians.

Plumbers, Pipe Fitters, Steamfitters, Apprentices, and Supervisors

Elevated risks were observed for cirrhosis of the liver (PMR = 190) among plumbers, pipe fitters, steamfitters, apprentices, and supervisors.

Concrete and Terrazzo Finishers and Glaziers

Significant increased risks for MN of the skin (PMR = 319), cirrhosis of the liver (PMR = 203), and other accidents (PMR = 154) were reported among concrete and terrazzo finishers and glaziers.

Mechanics and Repairers

Mechanics and repairers experienced elevated PMRs for MN of the pancreas (PMR = 187).

Drywall Installers

Among drywall installers, elevated PMRs were observed for respiratory tuberculosis (PMR = 675), MN of the skin (PMR = 363), transportation accidents (PMR = 145), and homicide (PMR = 157).

Roofers

Roofers were observed to be at increased risk of death as a result of cirrhosis of the liver (PMR = 158), other diseases of the digestive system (PMR = 191), accidental falls (PMR = 407), and homicide (PMR = 207).

Insulators

Elevated PMRs were observed for pneumonoconiosis and other respiratory diseases (PMR = 218), and homicide (PMR = 232) among insulators.

Welders and Cutters

Excess mortality was observed for hypertension without heart disease (PMR = 575) and accidental falls (PMR = 362) among welders and cutters.

Operating Engineers and Heavy Equipment Operators

Operating engineers and heavy equipment operators showed elevated PMRs for MN of the trachea, bronchus, and lung (PMR = 116), emphysema (PMR = 191), cirrhosis of the liver (PMR = 142), and symptoms and ill-defined conditions (PMR = 185).

All Other Construction Craft Workers, NEC (not elsewhere classified)

Accidental falls (PMR = 398) and homicide (PMR = 157) PMRs were elevated among all other construction craft workers, NEC. Ischemic heart disease was significantly reduced among workers in these trades (PMR = 77).

Construction Supervisors, NEC

Construction supervisors had elevated PMRs for MN of the trachea, bronchus, and lung (PMR = 119), MN of connective tissue (PMR = 215), and transportation accidents (PMR = 128).

Construction Engineers, and Managerial, Professional Speciality Occupation

Construction engineers, and managerial, professional speciality occupation categories had elevated PMRs for MN of the pancreas (PMR = 154), MN of other parts of the respiratory system (PMR = 302), MN of the prostate (PMR = 134), other neoplasms of lymphatic and hematopoietic tissue (PMR = 153), and diseases of the arteries, veins, and pulmonary circulations (PMR = 131).

All Other Construction-Related Occupations

All other construction-related occupations were found to have elevated PMRs for other diseases of the genitourinary system organs (PMR = 154), accidental poisoning (PMR = 197), and other accidents (PMR = 157).

Comparison of Deaths Resulting from Selected Causes across Trades

Several interesting patterns emerged when overall mortality results and data across trades were compared. Table VI provides a comparison of mortality for selected cancers. Cancers of the buccal cavity and pharynx are listed because they were found to be significantly elevated overall. In addition, cancers of the peritoneum and other parts of the respiratory system are listed because these are categories where asbestos-induced mesotheliomas would be coded. A total of 16 deaths were coded to ICD-9 code 163, mesotheliomas of the pleura. An additional nine deaths were coded to ICD-9 categories generally used for peritoneal mesotheliomas (158.8 and 159.9). Increased risk for cancers of the buccal cavity and/or pharynx was observed in all trades except engineers and managers. Lung cancer was in excess for each of the construction trades although not always reaching statistical significance.

Mortality for selected non-malignant respiratory diseases by trade is given in Table VII. Respiratory tuberculosis was significantly elevated for laborers and drywall installers and increased

TABLE VI

Mortality among North Carolina construction workers deaths resulting from selected cancers by trade

Construction trade or skill	PMR by cause (ICD-9 codes)				
	Buccal cavity (142–145)	Pharynx (146–149)	Peritoneum[a] (158–159)	Lung (162)	Other respiratory[b] (160, 163–165)
Carpenters	114	138	43 (1)	119*	75 (1)
Laborers	245*	112	239* (2)	102	—
Painters, Paperhangers, and Plasterers	174	178*	46 (1)	118*	39
Brick Masons, Stonemasons, Tile Setters	171	76	145 (2)	118*	—
Electricians, Electrical Power Installers	137	113	—	115	167 (2)
Plumbers, Pipe Fitters, Steamfitters	192	157	99	106	168 (2)
Concrete and Terrazzo Finishers/Glaziers	116	155	—	103	—
Mechanics and Repairers	—	166	—	125	178 (1)
Drywall Installers	—	133	—	110	—
Roofers	507*	176	304 (1)	110	—
Insulators	—	—	—	153	—
Welders and Cutters	278	—	435	127	—
Operating Engineers/Equip. Operators	97	155	81	116*	137 (2)
All Other Craft Workers, NEC	187	301*	312	119	245
Construction Supervisors, NEC	—	160	51 (1)	119*	174 (3)
Engineers, Managerial Administrative	79	88	61 (1)	109	302 (4)
All Other Occupations	151	131	61	101	58 (1)

[a]These categories would include mesotheliomas of the peritoneum. The numbers in parentheses are the number of deaths coded specifically to ICD-9 codes 158.8 or 159.9.

[b]These categories would include mesotheliomas of the pleura. The number of deaths coded specifically to 163 is shown in parentheses.

* $p < 0.05$.

TABLE VII

Mortality among North Carolina construction workers deaths resulting from selected non-malignant lung diseases by trade

Construction trade or skill	PMR by cause (ICD-9 codes)				
	Respiratory TB (010–012)	Bronchitis (490–491)	Emphysema (492)	Asthma (493)	Pneumoconiosis (470–478, 494–519)
Carpenters	133	123	84	104	114*
Laborers	189*	96	98	67	118*
Painters, Paperhangers, and Plasterers	147	161	109	85	152*
Brick Masons, Stonemasons, Tile Setters	45	73	136	28	95
Electricians, Electrical Power Installers	—	46	101	102	96
Plumbers, Pipe Fitters, Steamfitters	111	88	130	95	104
Concrete and Terrazzo Finishers/Glaziers	90	—	168	70	84
Mechanics and Repairers	—	94	180	—	131
Drywall Installers	675*	—	—	—	45
Roofers	213	200	104	98	91
Insulators	—	—	145	—	218*
Welders and Cutters	—	—	107	—	73
Operating Engineers/Equip. Operators	85	142	191*	—	107
All Other Craft Workers, NEC	—	303	147	135	103
Construction Supervisors, NEC	—	79	90	52	108
Engineers, Managerial, Administrative	—	115	57	96	93
All Other Occupations	94	144	96	51	100

* $p < 0.05$.

TABLE VIII
Mortality among North Carolina construction workers deaths resulting from alcoholism, liver cirrhosis, and mental disorders by trade

Construction trade or skill	PMR by cause (ICD-9 codes) Alcoholism (303)	Liver cirrhosis (571)	Mental disorders (209–302) (304–319)
Carpenters	173*	114	99
Laborers	153*	124*	138*
Painters, Paperhangers, and Plasterers	212*	155*	129
Brick Masons, Stonemasons, Tile Setters	95	140*	99
Electricians, Electrical Power Installers	181*	154*	92
Plumbers, Pipe Fitters, Steamfitters	119	190*	111
Concrete and Terrazzo Finishers and Glaziers	120	203*	131
Mechanics and Repairers	119	118	79
Drywall Installers	103	113	55
Roofers	156	158*	23
Insulators	—	83	—
Welders and Cutters	193	115	—
Operating Engineers/Equip. Operators	121	142*	80
All Other Craft Workers, NEC	160	137	184
Construction Supervisors, NEC	92	89	98
Engineers, Managerial Administrative	115	106	114
All Other Occupations	130	114	117

* $p < 0.05$.

for carpenters, painters, plumbers, and roofers. Pneumoconiosis mortality was statistically elevated for carpenters, laborers, painters, and insulators. Operating engineers had a significantly increased risk of death caused by emphysema and several other trades had an elevated emphysema risk but not at a statistically significant level.

Alcoholism and cirrhosis of the liver were found to be significantly elevated overall and across construction trades as summarized in Table VIII. Alcoholism was elevated for all trades except brick masons, and liver cirrhosis was increased for all except insulators. Laborers were at an elevated mortality risk resulting from mental disorders.

A comparison of risks attributable accidental causes across trades is provided in Table IX. Transportation accidents were significantly elevated for carpenters, electricians, and drywall installers. Accidental poisonings were increased among laborers, drywall installers, and other occupations. Roofers were found to have the highest risk of death caused by accidental falls, followed by welders, other construction crafts, brick masons, and laborers. All trades except engineers and managers were found to have an increased risk of violent deaths resulting from homicide. Data available for this study do not allow further determination of what proportion of these homicides are a result of violence in the workplace. The authors have underway another study using data from the North Carolina Coroner's Office that shed more light on this issue.

DISCUSSION

These results are consistent with previous studies that have shown significantly elevated mortality due to diseases of the respiratory system among construction workers. Lung cancer ($n = 3{,}023$) accounted for a high proportion of the cancer deaths and was constantly elevated among White males, Black males, and males in many construction trades (Table VI). Three previous PMR studies of U.S. construction workers have shown similar patterns of elevated mortality.[5,7,14] These studies reported excess lung cancer and mesothelioma among construction workers. Robinson's study of construction workers, based on an analysis of 876,731 death certificates from 19 states during 1984–1986, demonstrated statistically significant PMRs for lung cancer among Black and White female construction workers, White males under age 65 at death, and for construction workers in many of the skilled trades and for laborers.[7] In the PMR study by Stern et al.,[5] which used death certificates of 11,685 members of the Laborers' International Union of North America during the period 1985–1988, the lung cancer risk was elevated consistently regardless of the year of first union membership

TABLE IX
Mortality among North Carolina construction workers deaths resulting from accidental causes and violence by trade

Construction trade or skill	PMR by cause (ICD-9 codes)				
	Trans. accidents (880–848, 929.0–929.1)	Accidental poisoning (850–869, 929.2)	Accidental falls (880–888, 929.3)	Other accidents (890–928, 929.4–929.9)	Homicide (960–959)
Carpenters	121*	123	97	122*	159*
Laborers	99	130	147*	131*	148*
Painters, Paperhangers, and Plasterers	96	185*	116	121	180*
Brick Masons, Stonemasons, Tile Setters	87	114	190*	126	130*
Electricians, Electrical Power Installers	126*	144	80	162*	58*
Plumbers, Pipe Fitters, Steamfitters	98	117	98	113	127
Concrete and Terrazzo Finishers/Glaziers	96	172	—	154*	130
Mechanics and Repairers	98	137	84	110	144
Drywall Installers	145*	211*	122	33*	157*
Roofers	101	118	407*	122	207*
Insulators	84	233	302	80	232*
Welders and Cutters	117	167	362*	181*	103
Operating Engineers/Equip. Operators	109	52	130	120	127
All Other Craft Workers, NEC	71	183	398*	142	157*
Construction Supervisors, NEC	128*	118	147	94	108
Engineers, Managerial Administrative	95	70	126	110	72
All Other Occupations	103	197*	83	157*	111

* $p < 0.05$.

or race. Exposure to asbestos in the construction industry is reported to be associated with an elevated risk of lung cancer.

White and Black male construction workers were found to have significantly elevated risks of accidental death including transportation accidents, accidental poisoning, accidental falls, and other accidents. In a study of nonfatal injuries of carpenters, falls were the most common cause of injury.[15] Suruda[16] found that 50 percent of occupational deaths among painters were from accidental falls. Similarly, an emergency department-based surveillance program of construction worker injuries observed that a large majority of severe hospitalized injuries resulted from falls. Hunting et al.[17] reported that more than half of the fall-related accidents among construction workers in their emergency department surveillance study were from scaffolds.

A significant elevation in mortality resulting from liver cirrhosis was found in White male construction workers (PMR = 137). The PMR for alcoholism was significantly elevated among White males (PMR = 162), Black males (PMR = 128), and for carpenters, laborers, and electricians and was increased, although not at a statistically significant level, for most other construction trades. In a study conducted by Leigh and Jiang[18], male construction workers were found to have the highest standardized mortality ratios (SMR) for liver cirrhosis among occupations studied. It is widely accepted that ingestion of alcohol is a risk factor for liver cirrhosis. Trice and Sonnenstuhl[19] found that among construction workers a high proportion of individuals drink heavily. Their study also suggested that blue-collar workers, such as workers in the construction trades, have a greater risk of liver cirrhosis than white-collar workers.

New findings of this study include excess risks for the following construction trades: (1) increased risk for other diseases of male genital organs among carpenters, carpenter apprentices, and supervisors; (2) elevated respiratory tuberculosis mortality among construction laborers and drywall workers; (3) elevated risk of death caused by diseases of the arteries, veins, and pulmonary circulation for brick masons, stonemasons, tile setters, apprentices, and supervisors; (4) stomach cancer excess among electricians, electrical power installers and repairers, and apprentices and supervisors; (5) excess skin cancer among concrete and terrazzo finishers and glaziers and among drywall installers; (6) elevated pancreatic cancer risk for mechanics and repairers; (7) excess risk of hypertension among welders and cutters; (8) increased risk of emphysema for operating engineers and heavy equipment operators; (9) increased mortality resulting from cancer of the connective tissue among construction supervisors; and (10) increased risks for cancers of the pancreas, cancer of the prostate, and other neoplasms of lymphatic and hematopoietic tissue and diseases of the arteries, veins, and pulmonary circulation among construction engineers and managers.

Smoking and exposure to heavy airborne concentrations of dusts, fumes, and gases are associated with higher rates of emphysema. Operating engineers and heavy equipment operators are exposed to diesel exhaust emissions which are a mixture of gases and particles including carbon monoxide, oxides of nitrogen and sulphur, and fine particles. Consistent with our results, Wong et al.'s[20] study found significantly high mortality from emphysema among male members of a heavy construction equipment operators' union. Exposure to diesel exhaust is associated with an increased risk of lung cancer.[21,22] Operating engineers in the current study have a significantly increased lung cancer risk. Operating engineers also have a high prevalence of cigarette smoking.

Welders and cutters are exposed to increased levels of total particulate metals (chromium, nickel, copper, and other metals), nitrogen oxides, ozone, carbon monoxide, and other pollutants.[23] Significant positive associations have been reported between work as a welder and lung cancer and stomach cancer. Welding with coated electrodes has shown higher cancer risks than the other welding processes which might be a result of the exposure to chromium fumes, shown to be associated with lung cancer.[24,25] Our results did not show a statistically significant excess of lung cancers for welders and cutters a possible result of the small number of deaths in this trade category although the lung cancer PMR was 127.

Increased stomach cancer risk, observed for electricians, electrical power installers and repairers, apprentices, and supervisors, has been linked with exposure to dusty work environments. Excess stomach cancer has previously been observed among brick masons, stonemasons, and cement workers.[26,27] A study among Swedish men of stomach cancer incidence by industry and occupation found statistically significant excesses of stomach cancer among construction workers and also for plumbers, masonry, and concrete workers.[28]

According to the Bureau of Labor Statistics Annual Survey of Occupational Injuries and Illnesses, construction workers have the highest rate of occupational skin cancer, behind agricultural and manufacturing workers.[29] An elevated risk of skin cancer was observed for concrete and terrazzo finishers and glaziers and among drywall installers. Skin cancer has been shown to be caused by coal tar products, cutting oils, and ultraviolet radiation.[7,30–32] Chromium, including hexavalent chromium, is found in concrete and is a well-recognized cause of contact dermatitis and has been implicated as a cause of lung cancer among masons.[33,34]

An increase in cancers of the prostate among construction engineers, managerial, and professional speciality occupations has been reported among operating engineers by Decoufle et al.[35] Spear et al. found greater than expected morbidity from prostatitis among heavy equipment operators compared to repair and maintenance workers.[36] Previous studies have reported elevated prostate cancer risks only for Black mechanics and repairers who might be exposed to diesel fumes and lubrication oils.

Construction laborers perform most of the heaviest and most dangerous job tasks in the construction industry, and their changing work sites exposes them to various sources of occupational hazards. Laborers are exposed to asbestos, inorganic lead, solvents, carbon monoxide, diesel exhaust, welding fumes, and noise on their work sites.[5] Our study found laborers to be at an increased risk for cancer of the peritoneum which has been linked with asbestos. Stern's study also suggested that construction laborers are at an increased risk for stomach cancer which might be associated with asbestos exposure, wood dust, and cement.[5] While our stomach cancer PMR for laborers was increased (PMR = 110), this excess was not statistically significant; however, we did observe increased mortality because of cancer of the esophagus. Laborers also were found to be at increased risk for death resulting from pulmonary tuberculosis, consistent with previous reports. Drywall workers in our study also were found to be at increased risk of death caused by pulmonary tuberculosis.

Strengths and Limitations

Studies of mortality using death certificates are useful surveillance tools for identifying potentially hazardous occupations and industries. These data are low-cost and easy to access. However, the data lack exposure histories as well as information on non-occupational risk factors, such as smoking and diet, which may be important in evaluating mortality rates. Internal comparisons, such as the use of a blue-collar referent population, partially control for non-occupational risk factors.

The inaccuracy of usual occupation coded using death certificates may bias study results. Misclassification of occupation and industry data on the death certificates was reported to be between 30 to 50 percent in a study comparing death certificate occupation and industry data with lifetime occupational histories obtained by interview.[37] This suggests that the utility of death certificate data for investigations into the occupational risk factors for cancer may underestimate the risk of specific groups because of misclassification. Our study also reported only statistically significant increased or decreased PMRs where there were at least five observed deaths. This was done to eliminate reporting of highly unstable ratios; however, this limited our ability to report on less common causes of death. Therefore, absence of statistically elevated mortality by trade does not negate positive associations found in other studies.

Limitations of proportionate mortality study methods are well known. Because the sum of all PMRs (expressed as weighted fractions) must equal one, an excess in one disease must be offset by a deficit in another disease. The magnitude of each cause of death is thus dependent upon the magnitude of PMRs for other causes of death.[5] However, studies have shown that PMRs are useful indicators of disease risk, and our study confirmed previous findings of increased mortality risks among construction workers. Finally, this surveillance study performed many mortality determinations by trade and cause, thus many statistical tests of significance were performed. A number of statistically significant findings would be expected by chance. We have attempted to reduce the chance of false positive findings in a number of ways including: (1) requiring that any positive finding be based

on at least five observations, (2) use of a conservative test statistic and (3) use of the 0.05 level for tests of statistical significance in a two-tailed test.

CONCLUSIONS

Our study provides mortality surveillance data for a largely non-union workforce that are useful for comparison with other published data for workers in the construction industry. Some findings offer insight into needed prevention efforts, and others provide clues for additional etiologic research using other epidemiological study designs such as nested case-control analyses and possibly cohort mortality analyses. Deaths as a result of falls from elevations and electrocutions are clearly elevated among this population and require additional prevention efforts.

Cancer mortality was found to be excessive for a number of sites with well-established occupational risk factors including cancers of the buccal cavity, pharynx, lung, pleura, and peritoneum. Preventive efforts to reduce exposures to materials such as asbestos, wood dusts, and silica should help reduce these cancer risks.

Finally, several findings point to much-needed prevention efforts for non-occupational conditions such as alcoholism among many construction trades, respiratory tuberculosis among laborers and drywall workers, and accidental poisonings caused by drugs and alcohol among painters and drywall workers. The prevalence of smoking has been shown to be high among construction workers smoking prevention programs for this workforce need further attention.[38]

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