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Surveillance of Construction Worker Injuries: The Utility of Trade-Specific Analysis

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Construction is a dangerous industry, with high rates of both fatal and nonfatal injuries. To learn more about the causes of nonfatal construction worker injuries, and to identify injury cases for further work site-based investigations or prevention programs, we established an emergency department-based surveillance program in November 1990. This article describes circumstances of injury, diagnoses, and demographic characteristics of injured construction workers for 2,791 cases identified through mid-August, 1997. Lacerations and strains and sprains were the most frequent diagnoses; cutting and piercing objects were the leading causes of injury among all construction workers, followed by falls and overexertion. Because of the variety of work performed in this industry, more detailed injury descriptions, by trade, are most useful for thinking about injury prevention. To illustrate this, we profile injury patterns among workers from four specific trades: carpenters, electricians, plumbers, and ironworkers. Areas of concern highlighted by the trade-specific analyses include eye injuries among plumbers; falls from ladders among electricians and plumbers; slips, trips, and falls on the same level among ironworkers; electrical exposure among electricians; and, amputations among carpenters.

Keywords Construction, Occupational Injuries, Surveillance

Every day on the job, construction workers face a risk of nonfatal injury higher than that seen for any other group of U.S. workers.[1] Likewise, the risk of fatal work-related injury is over 2.5 times higher than that experienced by other U.S. workers in private industry, and 17 percent of all occupational fatalities occur in the construction industry.[2] Only two industries—mining, and agriculture, forestry and fishing—have higher fatal injury rates.

Construction work entails operation of heavy machinery and power tools, work at elevations, fabrication and installation of sharp-edged objects with sharp tools, overhead tasks, confined space work, cluttered work surfaces, and temperature extremes. Heavy material-handling tasks are performed by virtually every construction trade. By definition, the work environment is changing, requiring workers to be vigilant for new hazards. In addition, many construction workers change employers and work sites frequently.

Proportionate mortality studies[3–5] have indicated that construction workers younger than age 65 have more falls and other fatal injuries than expected. Prior studies have described injury circumstances and worker characteristics for case series of fatal construction injuries.[6–11] Several such studies were population-based and, in addition to describing cases, have also calculated rates of fatal construction injury by age, sex, ethnicity, occupational group, and other factors.[12–15] These case series studies have identified falls as the leading cause of construction fatality, with electrocutions, transportation-related deaths, and machinery-related deaths also near the top of the list. The circumstances of fatalities do, however, vary substantially by trade.[13]

Recently, researchers have focused increasing attention on nonfatal construction injuries. In addition to annual survey data published by the Bureau of Labor Statistics,[1] nonfatal injuries have been identified through workers' compensation data, emergency department records, and employer injury logs. Patterns of nonfatal injuries are distinct from those of fatalities.[16] Two large Occupational Safety and Health Administration (OSHA) studies[17,18] utilized workers' compensation data and included all construction trades. As with fatalities, the circumstances differ by trade, but the analyses by trade were not very detailed in the OSHA studies. An Ontario, Canada study[19] described lost-time construction injuries in considerably more detail and provides the best basis to date for establishing trade-specific prevention priorities. Two other sizable studies used workers'

compensation records and focused on single trades: a retrospective questionnaire survey of 3700 injured construction laborers,[20] and, a cohort study of union carpenters which described patterns and rates of occupational injuries and illnesses over a four-year period.[21,22]

Additional research has targeted particular types of injury: Gillen et al.[23] reviewed Doctor's First Reports of injury in California to identify nonfatal construction falls, then reviewed medical records and conducted followup personal interviews; and Payne et al.[24] identified woodworking injuries to carpenters and other workers through emergency departments. From these studies, a fairly comprehensive picture of nonfatal construction injury patterns has emerged. To develop trade-specific prevention programs, however, more detail is needed, especially for trades other than laborers and carpenters.

To learn more about the causes of nonfatal construction worker injuries, and to identify injury cases for further work site-based investigations or prevention programs, we established an emergency department-based surveillance program in November 1990. Results for the first two years were previously described.[25] This article extends these results through mid-August 1997, and summarizes trade-specific injury patterns for carpenters, electricians, plumbers, and ironworkers.

METHODS

Medical records were reviewed to identify construction workers with work-related injuries or illnesses treated in the George Washington University Emergency Department (ED) between November 1, 1990 and August 15, 1997. Methods for obtaining these data were previously described.[25] We included all workers in construction occupations, even those working for employers classified outside of Standard Industrial Classification (SIC) categories 15–17. Examples of tradespeople with non-construction industry employers are maintenance painters, carpenters, or plumbers employed by a university, government agency, or museum.

We included a case as work-related based on a combination of data in the medical record: the patient's presenting complaint; indication that the payment was to be through workers' compensation insurance; notes made by any treating health care worker about the circumstances of the injury; and, the physician's check in a box labeled "work-related."

The following data were abstracted from the medical record for each construction worker with a work-related condition: medical record number, name, address, state and zip code of residence, phone number, gender, date of birth, social security number, ethnicity (assessed visually by the registration clerk), employer name, city and state, occupation, up to two diagnoses, and the circumstances of injury. If a patient was admitted to the hospital we also noted discharge date. In early 1992, we also began recording the physicians' recommendations for days away from work and days on light duty. We coded occupation according to Standard Occupational Classification (SOC) codes.[26] Furthermore, diagnosis and E codes were assigned according to the International Classification of Diseases, 9th Revision (ICD-9).[27]

Abstraction was continuous except for July through December 1994. During this period, we abstracted data only on injuries from one large local construction project, and also on the most serious injuries which required the services of the ED trauma team. During these six months of partial data collection, we missed an estimated 200 additional cases.

RESULTS

Injury Patterns Among All Construction Workers

During nearly seven years of surveillance, we collected data on 2791 construction worker injuries. Table I describes the demographic characteristics and occupations of the injured workers. Almost all were male (97%). Forty-six percent were white, 33 percent were black, and 19 percent were Hispanic. The majority of the workers were between the ages of 25 and 44 (66%). Fourteen percent were younger than 25 and 5 percent were age 55 or over. Laborers, carpenters, and electricians lead the list of occupations, together representing more than half of all the injured workers in the database (21%, 20%, and 14% respectively). Almost eight percent of the injured workers identified themselves only as "construction workers" without specifying a trade; we have described these workers as "construction workers, NOS." Thirteen percent of the injuries in this database were experienced by construction trades workers with fixed-site or maintenance types of jobs (that is, outside of SIC 15–17). Because 211 workers were treated at the George Washington University ED more than once during the seven-year surveillance period, this case series represented 2539 different individuals.

Table II describes 3041 diagnoses among the 2,791 injury cases. We recorded up to two diagnoses per case; multiple diagnoses were present in 9 percent of cases. Thirty-seven percent of cases involved lacerations, with 60 percent of these injuries occurring to the fingers, hands, and wrists. There were also numerous face and head lacerations which most often occurred when workers were struck by or struck against sharp or heavy objects.

Twenty-two percent of all injury cases involved musculoskeletal strains, sprains, or pain. The low back was by far the most frequent injury location in this category. Additionally, 14 percent of injuries to construction workers involved contusions, abrasions, or foreign bodies to locations other than the eye. The legs and trunk were the most common body locations for these injuries. Eye injuries were also significant in number, accounting for just over one of every ten emergency department visits.

The more serious injuries included 236 fractures (8.5% of cases), 52 crush injuries (1.9%), 50 head injuries (1.8%), 21 amputations/partial amputations (< 1%), and 13 cases of carbon monoxide poisoning (< 1%). We have previously described an incident in which five workers were exposed to high levels of carbon monoxide while using gasoline-powered pressure

TABLE I

Demographic characteristics of injured contruction workers treated in the George Washington University Emergency Department, Nov. 1, 1990–Aug. 15, 1997 (2791 cases[A])

Characteristic	Number	(Percent)
Age		
< 25	388	(13.9)
25–34	1050	(37.6)
35–44	783	(28.1)
45–54	420	(15.0)
55+	140	(5.0)
Unknown	10	(0.4)
Gender		
Male	2702	(96.8)
Female	89	(3.2)
Race		
Black	915	(32.8)
White	1277	(45.8)
Hispanic	521	(18.7)
Asian/Pacific Islander	14	(0.5)
Other/unknown	64	(2.3)
Occupation		
Laborer	586	(21.0)
Carpenter	558	(20.0)
Electrician	379	(13.6)
Construction worker, NOS[B]	211	(7.6)
Plumber	153	(5.5)
Ironworker	127	(4.6)
Supervisor/foreman	120	(4.3)
Painter	108	(3.9)
Sheetmetal worker	85	(3.0)
Brick/stone mason	68	(2.4)
Plasterer/drywall worker	66	(2.4)
Asbestos/insulation worker	54	(1.9)
Roofer/waterproofer	47	(1.7)
Welder/boilermaker	34	(1.2)
Heavy equipment operator	32	(1.1)
Concrete finisher	30	(1.1)
Engineer/architect/ inspector	24	(0.9)
Carpet/floor layer	24	(0.9)
Elevator constructor/mechanic	22	(0.8)
Sprinkler fitter	18	(0.6)
Glazier	14	(0.5)
Other	31	(1.1)

[A]There were 2791 injuries involving 2539 workers during this time period. One hundred eighty-one (181) workers were seen twice, 21 were seen 3 times, 8 were seen 4 times, and 1 was seen 6 times. Workers seen multiple times were seen for different injuries each time. Each injury is counted in the above table.

[B]NOS = not otherwise specified.

TABLE II

Summary of diagnoses among construction workers treated in the George Washington University Emergency Department, Nov. 1, 1990–Aug. 15, 1997 (3041 diagnoses, 2791 cases)

Category of injury Most common diagnoses	No. of diagnoses	No. of cases[C]	(% of cases)
Laceration		1044	(37.4)
Finger/thumb	392		
Hand/wrist	239		
Face/head	200		
Elbow/arm	93		
Ankle/foot	59		
Knee/leg	55		
Sprains/strains and musculoskeletal pain		620	(22.2)
Low back	227		
Ankle/foot	90		
Hand/wrist	82		
Neck/shoulder	79		
Knee/leg	65		
Trunk/abdominal	36		
Elbow	24		
Finger/thumb	22		
Contusion/abrasion/foreign body[A]		402	(14.4)
Knee/leg	84		
Trunk/back	76		
Ankle/foot	59		
Finger/thumb	47		
Face/head	44		
Arm/elbow	36		
Neck/shoulder	30		
Wrist/hand	27		
Eye injuries		294	(10.5)
Abrasion	150		
Foreign object	87		
Conjunctivitis	23		
Fractures		236	(8.5)
Finger	69		
Ankle/foot	54		
Hand/wrist	39		
Spine/trunk	25		
Elbow/arm	24		
Other		363	(13.0)
Burn	52		
Crush injury	52		
Head injury and sequelae	50		
Dislocation	32		
Wound infections	29		
Toxic effects of chemicals[B]	25		
Amputation/partial amputation	21		
Carbon monoxide poisoning	13		
Other and unspecified injuries	90		

[A]Foreign bodies other than in eye (eg., splinter).

[B]Toxic effects of chemicals other than carbon monoxide.

[C]Number of cases with one or more injuries in each category. Eg., a worker with a finger laceration and a facial laceration would be counted only once in this column.

washers to prepare the floor of an enclosed parking garage for resurfacing.[28]

Table III summarizes the circumstances of these construction worker injuries. Almost 27 percent of injuries were related to cutting/piercing objects—not surprising given that 37 percent of all injuries were lacerations. Metal, razors and knives, power tools, and nails were most often responsible for these injuries. More than half of the injuries related to nails (42/70) resulted from workers stepping on nails that went through their work boots. We looked at the 89 power tool injuries in more detail and found that 76 were due to portable power saws, drills, screw guns, and nail guns. (An additional 32 injuries were caused by stationary power saws, and are included in the "Machinery" category.)

Falls (16.7%) were the second most frequent category of injury. The most serious and numerous falls occurred between levels—most often from ladders or scaffolds. In one case requiring hospital admission, a 55-year-old construction worker broke his clavicle and was diagnosed with a pneumothorax when he fell 12–15 feet from a scaffold. Another case involved a 47-year-old construction worker, who fell 8–10 feet when a wall collapsed, sustaining a broken elbow and a facial fracture. Twenty percent of the fall injuries resulted from slips, trips, and falls on the same level; these injuries often resulted in strains and sprains, lacerations, and other less severe injuries.

Almost 20 percent of the injuries resulted from workers being struck by or striking against objects; in about half these cases the objects fell on workers. A 52-year-old laborer was among the recent cases—he remained hospitalized for 14 days with a tibia fracture after 10 to 15 sheets of drywall fell on his lower leg. Another case involved a 23-year-old construction worker who sustained hand fractures when he was struck by a trash chute which fell off a building. Overexertion injuries represented an additional 12 percent of injuries. Lifting and carrying were the most frequent activities associated with these injuries and the low back was the most frequent site of injury. Other injury circumstances are summarized in Table III.

Over the entire surveillance period, 3.6 percent of construction workers were admitted to the hospital from the ED. Laborers accounted for 20.1 percent of injured workers, but 34.7 percent of admissions, while construction workers, NOS accounted for 7.6 percent of injured workers and 13.9 percent of admissions. Of the 101 admissions, over half (52) resulted from falls, most from scaffolds (21) or ladders (15). Even though the proportion of injuries requiring hospital admission has decreased slightly over the course of this surveillance project, the types and circumstances of serious injuries have not changed substantially. These more serious injuries will be described in a subsequent article.

TABLE III
Summary of injury circumstances for construction workers treated in the George Washington University Emergency Department, Nov. 1, 1990–Aug. 15, 1997 (2791 cases)

Category Most common circumstances (≥20 injuries)	#	(%)
Cutting or piercing objects	748	(26.8)
Metal/sheetmetal/steel	166	
Razor/knife	125	
Portable power tools	85	
Nails	70	
Hand tools	42	
Glass	40	
Metal stud	33	
Wire	32	
Light fixture/metal ceiling frame	25	
Falls	465	(16.7)
From ladder	124	
Slip, trip, stumble	93	
From scaffold	75	
From one level to another	52	
From stairs	25	
Out of a building/structure	24	
Into a hole	21	
Overexertion/strenuous movements	346	(12.4)
Lifting/carrying	194	
Stepping on/off, walking	27	
Pushing/pulling	26	
Struck by falling objects	277	(9.9)
Metal objects/rebar/plates/duct	33	
Pipes/poles	25	
Beams	23	
Boards/wood	21	
Struck by/against objects	256	(9.2)
Hammer/sledge	29	
Pipes/poles	26	
Metal/metal duct	23	
Wood/boards	22	
Beams	20	
Foreign object enters eye	240	(8.6)
Concrete/cement (dust/wet)	51	
Metal	42	
Dirt/dust/debris	25	
Chemical (liquid)	24	
Involving machinery	130	(4.7)
Stationary power saws	32	
Lifting machines, including cranes, elevators	32	
Caught in/between objects	117	(4.2)
Other circumstances	212	(7.6)
Electrical shock	51	
Toxic effects of substances	36	
Burns from chemicals/hot liquid/hot objects	26	
Involving a vehicle	23	

Trade-Specific Injury Data

Although analysis of the entire surveillance database is interesting, *overall* patterns of injury among construction workers do not usually provide sufficient detail to help target prevention activities. Given the variety of work performed in this industry,

more detailed injury descriptions, *by trade*, are more useful for thinking about injury prevention. To illustrate this, we will present data on injury patterns among workers from four specific trades: carpenters, electricians, plumbers/pipefitters/steamfitters (henceforth "plumbers"), and ironworkers.

These are the four most frequent trades in the surveillance database, except for laborers and "construction workers, NOS." We concluded that trade-specific analyses would not be as illustrative for laborers or for construction workers who do not specify a trade. The four selected trades together represent 44 percent of the injured construction workers in our case series: carpenters, 20 percent; electricians, 14 percent; and plumbers and ironworkers, each approximately 5 percent.

Table IV summarizes the diagnoses which are over-represented among each trade, compared to all construction workers, and Table V summarizes injury circumstances. For every trade except ironworkers, injuries caused by cutting/piercing objects are most frequent. Falls were the most frequent cause of injury for ironworkers and were the second leading cause of injury for carpenters and electricians.

To understand and prevent injuries, it is necessary to look at the circumstances in detail. Table VI describes the most frequent types of circumstances for injuries due to cutting and piercing objects, and Table VII examines the most frequent types of falls among the four trades. Referencing Tables IV–VII, injury patterns are described below for each of the trades.

TABLE IV

Diagnoses which are overrepresented among four trades, compared to diagnoses of all workers, George Washington University Emergency Department, Nov. 1, 1990–Aug. 15, 1997, $N = 2791$

Trade —overrepresented diagnoses	Percent of cases: Selected trade	Percent of cases: All workers	p-value[A]
Carpenters ($N = 558$) have:			
—more lacerations to the fingers/thumb/hand/wrist	30.5	22.6	< 0.01
—more contusions/abrasions to the fingers/thumb/hand/wrist	4.7	2.7	0.01
—more amputations	1.3	0.8	0.40
Electricians ($N = 379$) have:			
—more lacerations to the fingers/thumb/hand/wrist	27.4	22.6	0.04
—more eye injuries	14.5	10.5	0.02
—more burns and other injuries from electric shock	8.7	1.8	< 0.01
Plumbers ($N = 153$) have:			
—more eye injuries	19.0	10.5	< 0.01
—more lacerations and contusions/abrasions to the head/face	11.8	8.5	0.16
—more finger/hand/wrist fractures	5.9	3.9	0.22
—more neck/shoulder strains	5.2	2.8	0.14
—more knee/leg strains (excl. ankle/foot)	4.6	2.3	0.13
—more crush injuries	3.3	1.9	0.37
—more wound infections	2.6	1.0	0.14
Ironworkers ($N = 127$) have:			
—more strains/sprains/pain to the back	11.8	8.1	0.14
—more fractures to the upper extremities	7.9	4.7	0.10
—more strains/sprains/pain to the ankle/foot	6.3	3.2	0.10
—more strains/sprains/pain to the hand/wrist	4.7	2.9	0.36
—more crush injuries	3.1	1.9	0.50
—more fractures to the ankle/foot	2.4	1.9	0.97

[A] P-value represents the significance of the difference in injury proportions for selected trade versus all trades, based on Pearson's chi-square test. Yates corrected chi-square used for comparisons with expected cell values < 5.

TABLE V

Injury circumstances of construction workers treated in the George Washington University Emergency Department, for four trades compared to all construction workers, Nov. 1, 1990–Aug. 15, 1997

	Carpenters $N = 558$ %	Electricians $N = 379$ %	Plumbers $N = 153$ %	Ironworkers $N = 127$ %	All workers $N = 2791$ %
Cutting/piercing objects	34.9***	30.9*	15.0***	19.7*	26.8
Falls	12.9**	14.5	11.8	21.3	16.7
Overexertion	12.2	12.7	11.8	18.9**	12.4
Struck by falling object	8.4	5.8**	15.0**	10.2	9.9
Struck by/against object	8.2	8.7	12.4	11.0	9.2
Foreign object in eye	6.5*	10.0	15.0***	7.1	8.6
Involving machinery	5.9	1.8**	3.9	2.4	4.7
Caught between objects	6.5**	3.4	5.2	4.7	4.2
Electric shock	0.7*	8.7***	0.7	0.0	1.8
Toxic effect of substances[A]	0.4*	2.1	3.3*	0.0	1.3
Burns (chemical/hot liq./hot obj.)	0.0**	0.5	1.3	0.0	0.9
Other/unspecified	3.4	0.8***	4.5	4.7	3.5

The difference in injury proportions for selected trade versus all construction workers is based on Pearson's chi-square test (or Yates corrected chi-square for comparisons with expected cell values < 5). The significance of the difference is noted as follows:

* $p < 0.10$

** $p < 0.05$

*** $p < 0.01$

[A]Toxic effects of substances, including chemicals, carbon monoxide, and smoke.

Carpenters

Carpenters were treated for lacerations during 47 percent of their ED visits, the highest fraction among the four trades, and higher ($p < 0.01$) than for all construction workers (37.4%). This excess was principally explained by the high proportion of visits due to lacerations of the fingers/thumbs or hands/wrists (30.5% versus 22.6%, $p < 0.01$). "Metal," "sheetmetal," and "steel" were the most frequent agents of cutting and piercing injuries for all four trades, and were responsible for about one-fifth of such injuries among carpenters. Often, there was little detail in the medical record other than that the worker was cut on a piece of metal.

Portable power tools were the source of over one-fifth of the cutting and piercing circumstances among carpenters; many of these were portable power saws, however, drills, nail guns, and screw guns also accounted for a considerable number of injuries. One carpenter was admitted to the hospital with a nail in his femur after shooting himself in the knee with a nail gun.

Carpenters were frequently treated in the ED for injuries sustained while cutting with utility knives and razors. Other hand tools such as chisels and metal spatulas were also associated with injuries in this trade. Carpenters were also treated more often than other trades for contusions and abrasions to the fingers, thumbs, hands, and wrists.

TABLE VI

Most frequent types of cutting or piercing objects among construction workers treated in the George Washington University Emergency Department, for four trades, Nov. 1, 1990–Aug. 15, 1997

Carpenters ($N = 558$)		Electricians ($N = 379$)		Plumbers ($N = 153$)		Ironworkers ($N = 127$)	
Type of cutting or piercing object	% of all injuries	Type of cutting of piercing object	% of all injuries	Type of cutting or piercing object	% of all injuries	Type of cutting or piercing object	% of all injuries
All cut/pierce	34.9	All cut/pierce	30.9	All cut/pierce	15.0	All cut/pierce	19.7
Metal/sheetmetal/ steel	7.0	Metal/sheetmetal/ steel	6.1	Metal/sheetmetal/ steel	5.2	Metal/sheetmetal/ steel	6.3
Razor or knife	6.3	Light fixture	5.0	Nail	2.0	Wire	3.9
Portable power saw	3.0	Hand tools	3.7	Ceramic tile/fixture	2.0	Drill	3.1
Other power tools	4.5	Razor or knife	2.9	Pipe/pole	2.0	Rebar	1.6
Hand tools	2.7	Metal stud	2.1	Power tool (drill)	0.6	Nail	1.6

Table V shows that carpenters were disproportionately injured by machinery (5.9%), especially table saws and other types of stationary woodworking machinery. The most serious diagnosis over-represented among carpenters was amputations, all to the fingers or thumbs. Six of the seven amputations were from saws; the other worker sustained a fingertip amputation when it was crushed by a scaffold.

Falls represented a smaller proportion of carpenters' injuries than for all construction workers (12.9% versus 16.7%, $p < 0.05$). The most common scenario was a slip, trip, or fall on the same level. Same-level falls were followed in frequency by falls from ladders, between levels (NOS), and from scaffolds. Only 2.2 percent of all carpenters' injuries resulted in hospital admission. Half of these hospitalized cases were due to falls from height, and all but one resulted in fractures and/or head injuries. These fall circumstances were varied, and included a fall from a ladder, two falls from scaffolds, a fall from the back of a truck, and a 25-foot jump/fall from a falling steel column.

Electricians

Over 42 percent of all injured electricians were treated for lacerations. As with carpenters, the excess (compared with all construction workers) was due to lacerations of the fingers/thumbs or hands/wrists (27.4% versus 22.6%, $p = 0.04$). These injuries most frequently occurred when electricians were working with sharp metal (6.1%), and while installing, fixing, or changing light fixtures (5.0%). Hand tools such as hacksaws and screwdrivers were also associated with numerous injuries, as were utility knives and razors.

Electricians also had more eye injuries than other construction workers (14.5% versus 10.5%, $p = 0.02$). Almost one-third of these injuries took place when the worker was using a tool—most often, a drill. Over two-thirds of the eye injuries were caused by foreign objects, most often metal and concrete dust in the eyes.

Almost 9 percent of the electrician injuries were burns or other diagnoses related to electrical current exposure, a very significant excess. Injurious electricity exposures resulted from a number of circumstances—explosions, a tool contacting a positive on a fuse box, a sparking line, touching "live" cables or wires. A number of falls resulted when the electrical contact occurred while the worker was on a ladder.

Of the 379 electricians treated at the George Washington University ED during the surveillance period, 3.4 percent were admitted to the hospital. Electrical injuries accounted for over half of these admissions. One of these electricians suffered a fatal electric shock while working on a ladder. The actual circumstances of the injury are unknown; he was found on the ground by a co-worker. In another case, an electrician sustained a serious electrical shock and was admitted to the hospital after a 1300 volt cable exploded while he was working in a manhole.

Falls—especially falls from ladders—were an important cause of injury for electricians (falls from ladders comprised 6.1% of all injuries and 42% of all falls). Most ladder-related falls were from heights of three to ten feet, though some were higher. For example, a 35-year-old electrician sprained his ankle and foot when he fell 16 feet off a ladder onto concrete. As in most cases, the medical record in this instance did not specify the circumstances behind the fall.

Plumbers

Eye injuries accounted for a higher fraction of visits among plumbers than for any other trade (19.0% versus 10.5% for all workers, $p < 0.01$). As with electricians, most eye injuries among plumbers (79%) were due to foreign objects entering the eye. Among the 29 eye injuries to plumbers, several occurred when working overhead, four occurred while soldering or welding; two while grinding metal; three involved paint or paint chips, and at least three cases resulted from working with pressurized pipes. In many cases, however, the activities of the workers were vague (e.g., "working with steel, and got a piece in his eye").

There were several other categories of injuries that plumbers experienced more frequently compared to all construction

TABLE VII

Most frequent types of falls among construction workers treated in the George Washington University Emergency Department, for four trades, Nov. 1, 1990–Aug. 15, 1997

Carpenters ($N = 558$)		Electricians ($N = 379$)		Plumbers ($N = 153$)		Ironworkers ($N = 127$)	
Type of fall	% of all injuries	Type of fall	% of all injuries	Type of fall	% of all injuries	Type of fall	% of all injuries
All falls	12.9	All falls	14.5	All falls	11.8	All falls	21.3
Slip/trip/fall same level	3.4	From ladder	6.1	From ladder	5.9	Slip/trip/fall same level	6.3
From ladder	2.5	Slip/trip/fall same level	2.4	Slip/trip/fall same level	2.6	Unspecified	6.3
Between levels, NOS	2.0	Unspecified	1.8	On/from stairs	1.3	From ladder	3.1
From scaffold	1.8	Between levels, NOS	1.6	Unspecified	1.3	From roof or structure	2.4

workers, though due to small sample size the differences were not statistically significant. These included lacerations, contusions, and abrasions to the head and face; finger and hand fractures; neck, shoulder, knee, and leg strains; crush injuries; and wound infections.

Although plumbers suffered proportionally fewer lacerations and about the same proportion of contusions and abrasions as all construction workers combined, they did experience disproportionately more lacerations, contusions, and abrasions to the head and face (11.8% versus 8.5%, $p = 0.16$). The amount of time spent working overhead is likely to increase the risk of such injuries.

Table V shows that plumbers were injured by falling objects a higher proportion of the time (15.0%) than were any of the other three trades and than were all workers combined ($p < 0.01$). This contributes to the risk of head and face injuries, and is consistent as well with the increased proportion of finger and hand fractures and crush injuries in this trade.

Compared to other trades, plumbers experienced a lower proportion of injuries from falls. Falls from ladders, however, accounted for 5.9 percent of all injuries and half of all falls among plumbers, an increase compared to all construction workers. The importance of falls from ladders is similar to that pointed out for electricians—another mechanical trade which frequently installs and repairs overhead materials.

Of the 153 plumbers in this case series, six (3.9%) were admitted to the hospital. One case exemplifies the hazard to plumbers from working with pressurized systems; water from a ruptured standpipe blew a worker a distance of ten feet and he was hospitalized for five days with a leg fracture.

Ironworkers

Ironworkers may specialize in either structural steel construction or concrete-reinforcing ironwork; these subspecialties involve markedly different tasks and injury risks. Most of the injured ironworkers in our surveillance case series are probably concrete-reinforcing ironworkers (rodmen), given that local buildings are predominantly concrete construction.

Ironworkers were the only trade to be most commonly treated in the ED for sprains, strains, and muscular pain (29.9% versus 22.2% for all workers). Strains, sprains, and pain of the back were more frequent among ironworkers than among other construction workers (11.8% versus 8.1% for all trades, $p = 0.14$). Ironworkers were also treated proportionately more often (not statistically significant) for strains and sprains to the ankles, feet, hands, and wrists. Consistent with these diagnosis patterns, ironworkers experienced an especially large proportion of overexertion injuries (18.9% versus 12.4% for all workers, $p < 0.05$). More than half of these injuries occurred while lifting heavy objects such as rebar.

Of the four trades examined, ironworkers experienced the highest proportion of fractures (11.8%, compared to 8.5% for all workers). These fractures occurred disproportionately to the upper extremities and the ankles and feet. Crush injuries were another category of serious injury experienced more often by ironworkers than by other workers. None of these differences is statistically significant; we have a relatively small number ($N = 127$) of ironworkers in this case series.

Only 19.5 percent of all ironworker ED visits were caused by cutting and piercing objects, a lower fraction ($p < 0.10$) than for other construction workers. After the non-specific category of metal/sheetmetal/steel, wire (3.9%) presented the most frequent cutting/piercing hazard. These injuries were generally caused by the "tie wire" which is used to fasten rebar pieces together, keeping them in place during concrete pouring. These injuries occurred not only to hands, as one might expect, but to knees and arms as well.

We observed a higher proportion of falls among ironworkers than for any other trade. Falls from slips and trips on the same level, and cases in which the sites of the falls were not specified (but we think were most likely to be falls on the same level), together comprised almost 60 percent of the falls sustained by ironworkers. Some of these slips occurred when ironworkers were walking on rebar. Negotiating the rebar grid is made especially difficult when handling heavy materials. Table VI also shows that a substantial fraction of the ironworker injuries were due to falls from ladders, roofs, and structures. Four of the five hospital admissions among ironworkers were due to falls from height, including one fatally injured worker who fell 11 stories from a building onto windows stacked upright, and then onto gravel ground. Altogether, 3.1 percent of injured ironworkers were admitted to the hospital or died at the scene of injury.

DISCUSSION

Comparison to Other Research

Overall injury patterns will vary among surveillance systems, depending primarily on three factors: 1) the types of construction settings from which injured workers are identified (our surveillance system draws primarily from commercial new construction, commercial renovation, and maintenance work); 2) the distribution of trades that comprise the injury case series, and 3) the injury case-definition. For instance, lost-time injuries identified though workers' compensation records of employer logs will represent the most disabling cases, but will omit large numbers of injuries which require medical care. The composition of compensated lost-time injuries will also be influenced by state-to-state variation in the number of lost days before an injury is labeled as "lost-time."[17] Workers' compensation records and employer logs can also be used to identify all injuries involving medical treatment, and will consequently include the less urgent injuries (e.g., strains, cumulative trauma disorders) treated in primary care, chiropractic, or specialty referral settings. Our ED-treated case series omits injuries which do not require immediate treatment, but includes injuries to self-employed contractors who typically do not have workers' compensation insurance.

Our overall findings can be compared to construction worker injury patterns described by other researchers, beginning with the one employing the most similar case-definition. An emergency department-based surveillance project in rural Iowa[29]

described 88 construction work-related injuries. The diagnoses and circumstances were similar to our injuries, except that the proportion of burns was several times higher than ours.

We can also compare our injury patterns to those seen in four large series of nonfatal lost-time construction injuries:

- Bureau of Labor Statistics (BLS) Annual Survey data for 1993 (approximately the midpoint of our surveillance project).[30] Detailed data are available for injuries and illnesses involving lost work time (one day) or restricted activity.
- OSHA workers' compensation data from 10 states representing 359,000 lost-time construction injuries in 1985–1988.[17] The threshold for "lost-time" injuries varied from one to eight days; 73 percent of injuries came from states with one-day thresholds.
- Lost-time construction worker injuries (one-day threshold) identified on logs maintained by the U.S. Army Corps of Engineers from 1984–1988.[18] The Corps carries out a somewhat specialized mix of construction projects (e.g., waterways and bridges and military, federal construction projects).
- Lost-time injuries (one-day threshold) reported by employers to the Workers' Compensation Board of Ontario, Canada.[19]

The diagnosis and circumstance profiles from these four lost-time injury series are similar to each other; we therefore draw similar conclusions when comparing each of them to our ED data. In general, our ED-treated injuries include about three times (proportionally) more lacerations, and about half the proportion of strains, sprains, and musculoskeletal pain. In addition, fractures comprise a smaller proportion of our ED cases. Body location of injury also differed: upper-extremity injuries were over twice as common in our case series, back injuries were about half as common, and eye injuries were somewhat more common. Our data include smaller fractions of injuries due to falls and overexertion, though it is somewhat difficult to compare injury circumstances because of differences in organization between E-codes and BLS event codes.

Fingar et al.[31] found similar differences when comparing emergency department-treated occupational injuries and lost-time workers' compensation data. Notably, the ED data for Athens County, Ohio showed fewer contusions, abrasions, and lacerations, and a greater percentage of dislocations, fractures, strains, and sprains than did the compensation claims. The severity of the injury (in terms of its effect on ability to work), and whether or not the injury requires emergency treatment are probably the most influential factors accounting for the differences seen in both our comparisons and the Ohio comparisons.

The Army Corps injury data[18] and the Ontario data[19] are summarized by occupation. In addition, three of the BLS lost-time injuries industry subgroups are fairly comparable to trades we focused on: plumbing/heating/air-conditioning, electrical work, and carpentry/floor work.[30] In general, the same broad differences are seen when evaluating injury patterns for specific trades as were described previously for all construction workers. The results from different surveillance sources reinforce each other in a number of areas that are important for setting prevention priorities. In our data (mostly rodmen) as well as the data for Ontario (rodmen) and Army Corps (all ironwork), ironworkers had a higher proportion of injuries due to slips, trips, and falls than did carpenters, electricians, or plumbers—emphasizing the importance of falls in this trade. Another area of concordance between our surveillance data and the Ontario and BLS lost-time injuries is that electricians and plumbers are treated for disproportionate numbers of eye injuries, compared to other trades. Amputations are rare, but serious; our ED data, the Ontario data, and the BLS data indicate that carpenters are experiencing proportionally more amputations than other trades. Finally, an observation apparent in our data and in the Ontario and Army Corps data is that electrical current exposures account for a substantial proportion of injuries to electricians. Attention to these highly preventable injuries would result in decreases in both fatal and nonfatal injuries among electrical workers.

Lipscomb et al.[21,22] evaluated workers' compensation claims for a cohort of union carpenters. This study is distinct from other workers' compensation-based reports in that it includes both medical only claims and lost work-time claims. Strains, sprains, and other musculoskeletal conditions comprise a lower proportion of our ED-treated carpenter injuries than of the compensation claims (20% versus about 31%). Lacerations are treated in a higher proportion of ED injuries (47% versus 23%). These patterns are similar to—but not quite as pronounced as—those seen for previous comparisons between our ED data and lost-time injuries. It is interesting to note that falls comprise almost identical proportions of the two injury series.

Our data show that falls from height are responsible for 17 percent of ED-treated construction worker injuries and accounted for over half of the hospital admissions. Eleven percent of our falls (52/465) required hospital admission, a figure that agrees closely with data collected by Gillen and colleagues.[23] As falls from height are also the leading cause of construction worker deaths (see Introduction), appropriate implementation of fall prevention measures would reduce fatal as well as serious nonfatal injuries in the construction industry. As the trade-specific data in Table VII point out, and as the Ontario data[19] and Gillen et al.[23] also showed, circumstances of falls vary by occupation. For instance, one observation supported by both our data and the Ontario data is that a high proportion of falls among both electricians and plumbers are from ladders; the next question is to explore specific risk factors for falls during ladder use. The most successful prevention strategies will be tailored to the tasks of each trade.

Limitations

This surveillance program has a number of limitations—the most important being the lack of information about the population at risk. Even with a good estimate of the number of

construction workers in the area, it would be impossible to calculate injury rates, because the George Washington University ED is only one of numerous emergency departments in the Washington, D.C. metropolitan area. Thus our analyses summarize and compare proportional distributions of worker and injury characteristics, rather than rates.

To provide insight into this issue, we compared the proportional distribution of gender, race, and occupation in this case series to data from the 1990 census data for the Washington, D.C.—MD—VA Metropolitan Statistical Area.[32] The breakdown of our injury cases by gender was almost identical to that of construction occupations from the census data. Comparison by race, on the other hand, showed considerable overrepresentation in our injury data for black workers, slight overrepresentation for Hispanics, and substantial underrepresentation for whites.

Comparison of proportional representation by occupation revealed quite similar proportions for most trades. The trades with differing representation are as follows:

	% of injury surveillance	% of census construction trades	Difference (surv–cens)
Construction workers, NOS	7.6	—	+ 7.6%
Laborers	21.0	15.1	+ 5.9%
Electricians	13.6	9.0	+ 4.6%
Ironworkers	4.6	0.7	+ 3.9%
Heavy equipment operators	1.1	4.5	- 3.4%
Painters/ paperhangers	3.9	9.2	- 5.3%
Supervisor/ foreman	4.3	13.5	- 9.2%

These differences may be due to: 1) real differences in the risk of injuries requiring emergency treatment between trades; 2) selection differences in the distribution of trades working in the vicinity of the George Washington University ED versus the whole metropolitan area; 3) changes in the trade-specific distribution of construction workers since the 1990 census; 4) misclassification on the emergency department record; or 5) differences in occupational definitions between SOC and census classification. Many of the workers labeled "Construction Worker, NOS" are probably laborers, and the difference seen for these two categories combined is quite substantial. We believe—given what our data show regarding the overrepresentation of hospitalized injuries in these two groups—that the difference shown above probably reflects a real increased risk of injury for the least-skilled construction workers. Similarly, the substantial difference between percent of injured and percent of census for supervisors and foremen probably reflects a real decrease in injury risk. We have no data to suggest an explanation for the differences between census data and injury surveillance data for other trades.

Using data from a series of followup surveys with injured workers, we have assessed the degree to which we may have included workers with non-construction occupations, or with injuries not related to work. From five telephone followup studies in which we spoke to 489 individuals, 1.8 percent were found not to do construction work, and an additional 1.2 percent were found to have injuries that were not work-related. We exclude these misclassified cases once we learn of our error, however, a similar amount of misclassification may exist among the surveillance cases whom we have never contacted through followup studies. Conversely, we may have missed eligible cases when abstracting medical records.

Emergency department surveillance captures some cases that are less likely to show up in other surveillance systems, such as injuries to self-employed individuals (an important construction subgroup), and injuries involving no lost work days. EDs do not, however, include all nonfatal injuries requiring medical attention; the most likely types of injuries to be underrepresented are chronic or sub-acute conditions where treatment can be delayed. In fact, our ED data showed substantially smaller proportions of strains, sprains, and musculoskeletal pain than did any of the other surveillance systems based on workers' compensation or employer logs. Despite this limitation, ED records are a rich resource for the identification of nonfatal injuries and are likely to capture virtually all injuries which require immediate medical attention.

Utility of Trade-Specific Analyses

We have presented descriptive data on injuries among specific trades in construction, an approach we believe will lead to more effective prevention of occupational injuries in this industry. Surveillance identifies and describes the problems, and may also begin to identify risk factors. It is but the first step in a cascade of steps in the prevention of injury and disease. Surveillance must be followed by more detailed identification of risk factors, development of interventions, evaluation of the interventions, and diffusion of the intervention through the community.

The construction industry is made up of many trades. For years, we have known that construction workers have more fatal and nonfatal injuries than workers in other industries, but research to identify risk factors and test interventions has been slow to follow. Researchers find that the mobile nature of both the construction work site and the construction workforce, coupled with the multitude of trades and tasks, make prevention work in construction a "moving target."

Analyses such as this one can identify high-risk groups for prevention activities. Narrative data from injury surveillance, and more detailed information from targeted research can then be used to identify risks and develop interventions. By looking at trade-specific patterns, we can identify:

- the trade with the highest proportion of certain injury diagnoses, such as fractures, crush injuries, or puncture wounds to the foot;

- the trade with the highest proportion of serious injuries (requiring hospitalization);
- the trade with the highest proportion of injuries to a specific body part, such as low back injuries, eye injuries, or hand and finger injuries; and
- the trade most affected by a specific circumstance, such as a fall from one level to another, or contact with electrical current.

Employers, unions, government agencies, and researchers will rely on different goals to set priorities for research and prevention. An ophthamologist seeing serious penetrating injuries to the eye may want to identify the trades most at risk of eye injury, to develop an educational program. A large construction employer who is self-insured for workers' compensation may want to identify the most costly injuries, identify the trades that are at risk for those injuries, and then find the circumstances that most often lead to those injuries in each trade. A smaller employer of one trade will want to know the patterns of injury in that trade, with enough description to understand the risk factors. Union health and safety programs would likely take the same approach.

Surveillance data on serious or fatal injuries such as electrocution in construction assist NIOSH in recommending work practices or engineering that are appropriately targeted toward the most at-risk trades and tasks. Trade-specific analyses, with detailed descriptions of the injury circumstances, provide opportunities for surveillance data to address each of these goals.

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REFERENCES

1. Bureau of Labor Statistics: Workplace Injuries and Illnesses in 1996 (http://www.osha.gov/oshstats/bls). U.S. Department of Labor/Bureau of Labor Statistics, Washington, D.C. (1998).
2. Bureau of Labor Statistics: Census of Fatal Occupational Injuries, 1992–1996. U.S. Department of Labor/Bureau of Labor Statistics, Washington, D.C. (1997).
3. Robinson, C.; Stern, F.; Halperin, W.; et al.: Assessment of Mortality in the Construction Industry in the United States, 1984–1986. Am J Ind Med 28:49–70 (1995).
4. Stern, F.; Schulte, P.; Sweeney, M.H.; et al.: Proportionate Mortality Among Construction Laborers. Am J Ind Med 27:485–509 (1995).
5. Stern, F.B.; Sweeney, M.H.; Ward, E.: Proportionate Mortality Among Unionized Construction Ironworkers. Am J Ind Med 31:176–187 (1997).
6. Occupational Safety and Health Administration: Analysis of Construction Fatalities—the OSHA Data Base 1985–1989. U.S. Department of Labor/Occupational Safety and Health Administration, Washington D.C. (1990).
7. Bureau of Labor Statistics: Issues in Labor Statistics: New Data Highlight Gravity of Construction Falls (Summary 96-1). U.S. Department of Labor/Bureau of Labor Statistics, Washington, D.C. (1996).
8. Pratt, S.G.; Kisner, S.M.; Moore, P.H.: Machinery-Related Fatalities in the Construction Industry. Am J Ind Med 32:42–50 (1997).
9. Suruda, A.J.: Work-Related Deaths in Construction Painting. Scand J Work Environ Health 18:30–33 (1992).
10. Suruda, A.; Smith, L.: Work-Related Electrocutions Involving Portable Power Tools and Appliances. J Occup Med 34:887–892 (1992).
11. Trent, R.B.; Wyant, W.D.: Fatal Hand Tool Injuries in Construction. J Occup Med 32:711–714 (1990).
12. Ore, T.; Stout, N.A.: Risk Differences in Fatal Occupational Injuries Among Construction Laborers in the United States, 1980–1992. J Occup Environ Med 39:832–843 (1997).
13. Pollack, E.S.; Griffin, M.; Ringen, K.; et al.: Fatalities in the Construction Industry in the United States, 1992 and 1993. Am J Ind Med 30:325–330 (1996).
14. Sorock, G.S.; O'Hagen Smith, E.; Goldoft, M.: Fatal Occupational Injuries in the New Jersey Construction Industry 1983 to 1989. J Occup Med 35:916–921 (1993).
15. Buskin, S.E.; Paulozzi, L.J.: Fatal Injuries in the Construction Industry in Washington State. Am J Ind Med 11:453–460 (1987).
16. The Center to Protect Workers' Rights: The Construction Chart Book: The U.S. Construction Industry and Its Workers, 2nd ed. The Center to Protect Workers' Rights, Washington, D.C. (1998).
17. Occupational Safety and Health Administration: Construction Accidents: The Workers' Compensation Data Base 1985–1988, U.S. Department of Labor/Occupational Safety and Health Administration, Washington, D.C. (1992).
18. Occupational Safety and Health Administration: Construction Lost-Time Injuries: The U.S. Army Corps of Engineers Data Base 1984–1988. U.S. Department of Labor/Occupational Safety and Health Administration, Washington, D.C. (1992).
19. Construction Safety Association of Ontario: Injury Atlas: Ontario Construction Based on WCB Injury Reports from 1987 to 1989. Construction Safety Association of Ontario, Etobicoke, Ontario (1995).
20. Bureau of Labor Statistics: Injuries to Construction Laborers. Bulletin 2252. U.S. Department of Labor/Bureau of Labor Statistics, Washington, D.C. (1986).
21. Lipscomb, H.J.; Kalat, J.; Dement, J.M.: Workers' Compensation Claims of Union Carpenters 1989–1992: Washington State. Appl Occup Environ Hyg 11:56–63 (1996).
22. Lipscomb, H.J.: Workers' Compensation Claims of Union Carpenters: Letter to Editor. Appl Occup Environ Hyg 12:507–509 (1997).
23. Gillen, M.; Faucett, J.A.; Beaumont, J.J.; et al.: Injury Severity Associated with Nonfatal Construction Falls. Am J Ind Med 32:647–655 (1997).
24. Payne, S.R.; Waller, J.A.; Skelly, J.M.; et al.: Injuries During Woodworking, Home Repairs, and Construction. J of Trauma 30:276–280 (1990).

25. Hunting, K.L.; Nessel-Stephens, L.; Sanford, S.M.; et al.: Surveillance of Construction Worker Injuries Through an Urban Emergency Department. J Occup Med 36:356–364 (1994).
26. U.S. Department of Commerce/Office of Federal Statistical Policy and Standards: Standard Occupational Classification Manual, 1980. U.S. Department of Commerce, Washington, D.C. (1980).
27. U.S. Department of Health and Human Services: International Classification of Diseases, 9th Revision, Clinical Modification, 4th ed. U.S. Department of Health and Human Services, Washington D.C. (1991).
28. Nessel-Stephens, L.; Welch, L.S.; Weeks, J.L.; et al.: Carbon Monoxide Poisoning from Use of Gasoline-Fueled Power Washers in an Underground Parking Garage—District of Columbia, 1994. MMWR 44:356–357, 363–364 (1995).
29. Zwerling, C.; Miller, E.R.; Lynch, C.F.; et al.: Injuries Among Construction Workers in Rural Iowa: Emergency Department Surveillance. J Occup Environ Med 38:698–704 (1996).
30. Bureau of Labor Statistics: Occupational Injuries and Illnesses: Counts, Rates, and Characteristics, 1993, Bulletin 2478. Bureau of Labor Statistics/U.S. Department of Labor, Washington, D.C. (1996).
31. Fingar, A.R.; Hopkins, R.S.; Nelson, M.: Work-Related Injuries in Athens County 1982 to 1986: A Comparison of Emergency Department and Workers' Compensation Data. J Occup Med 34:779–787 (1992).
32. Bureau of the Census: Census Data for Washington D.C. SMSA, 1990 Equal Opportunity File (Detailed Occupation by Sex by Hispanic Origin and Race). U.S. Bureau of the Census.