Work-Related Knee Injuries Treated in US Emergency Departments

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Objective: To characterize work-related knee injuries treated in US emergency departments (EDs). **Methods:** We characterized work-related knee injuries treated in EDs in 2007 and examined trends from 1998 to 2007 by using the National Electronic Injury Surveillance System—occupational supplement. **Results:** In 2007, 184,300 (±54,000; 95% confidence interval) occupational knee injuries were treated in US EDs, accounting for 5% of the 3.4 (±0.9) million ED-treated occupational injuries. The ED-treated knee injury rate was 13 (±4) injuries per 10,000 full-time equivalent workers. Younger workers and older female workers had high rates. Strains/sprains and contusions/abrasions were common—frequently resulting from falls and bodily reaction/overexertion events. Knee injury rates declined from 1998 through 2007. **Conclusions:** Knee injury prevention should emphasize reducing falls and bodily reaction/overexertion events, particularly among all youth and older women.

Work-related knee injuries are common and often result in significant loss of productivity and health care expenditures. Most published knee injury data have focused on state-based workers' compensation data, establishment-based studies, specific types of knee injuries, or ergonomic evaluations. National surveillance of occupational knee injuries is limited primarily to two systems: the Bureau of Labor Statistics (BLS) Survey of Occupational Injuries and Illnesses (SOII) and the National Institute for Occupational Safety and Health (NIOSH) emergency department (ED) surveillance. Neither system has been used to systematically describe knee injuries in the United States. The latter data covering knee injuries and disorders are the subject of this report.

In 2010, the BLS SOII reported that knees were the second (9%) most commonly injured body part that resulted in 1 or more days away from work (DAFW) among private industry and state/local government employees.[1] Only back injuries (19%) exceeded knee injuries involving DAFW. The overall knee DAFW injury rate was 10.9 cases per 10,000 full-time equivalent (FTE) workers. State government workers (16.7) and local government workers (19.6) had nearly twice the knee DAFW injury rate as private industry workers (9.6). These knee injuries required a median of 15 DAFW compared with 8 DAFW for all types of injuries. In 2007 and 2008, "total incurred costs" per workers' compensation claim for knee injuries averaged $28,993.[2]

Within private industry sectors in 2010, the BLS reported that the Transportation and Warehousing sector had the highest knee injury DAFW rate (21.7 per 10,000 FTE workers), followed by the Utilities sector (17.0) and the Construction sector (13.2).[3] Among workers in state government, which are primarily service providing and public administration, the Health Care and Social Assistance sector had a knee DAFW injury rate of 34.1 per 10,000 FTE workers. Justice, Public Order, and Safety Activities workers had the rate of 35.9 per 10,000 FTE workers.[4] Most local government workers had similar rates, but Police and Fire Protection workers had particularly high DAFW knee injury rates (39.4 and 63.8 per 10,000 FTE workers, respectively).[5] Others have also reported knee injury estimates and issues in various industry sectors and occupations, including construction,[6–8] emergency responders,[9] health care,[10] mining,[11] and utilities.[12,13]

Two reports have detailed injury claims involving work-related musculoskeletal disorders (WMSDs) of the knee in monopolistic (single payer) state workers' compensation systems. Washington State experienced nearly 25,000 knee-WMSD claims at a cost of $494 million from 1999 through 2007.[14] Knee-WMSD claims had an average total direct cost of $20,222 and median cost of $1,900. Forty-nine percent of the claims involved indemnity payments for more than 3 days of lost work time. Whereas Ohio had about 90,000 knee-WMSD claims in the period 1999 to 2004, with an average total cost of $4957 and median cost of $515.[15] Only 29% of the knee-WMSD claims included indemnity payments in Ohio, a state that requires more than 7 days of lost work time for indemnity payments. Despite the significant difference in waiting period for indemnity payments, data from both states illustrate the economic burden to employers from knee WMSDs. These studies focused on WMSDs involving the knee, such as meniscal/ligamentous disruption, sprain/strain, tendinitis/bursitis/enthesopathy, chondromalacia patellae, ganglion/cyst, and synovitis. Except for meniscus or cartilage tears and sprains and strains, other claims for acute knee injuries were excluded.

Acute knee injuries are often secondary to direct blunt trauma or excessive tension applied to the joint. Collateral ligament sprains, cruciate ligament sprains, meniscal damage, contusion, and patellar dislocation or subluxation are commonplace.[16] Overuse injuries such as patellar tendinopathy, iliotibial band syndrome, cartilage disorders, medial plica syndrome, and bursitis are frequently caused by cumulative microtrauma from repetitive knee flexion and extension.[17] In 2010, sprains, strains, and tears were the leading diagnoses for knee injuries resulting in DAFW among private industry (56%)[18] and state and local government (51% each).[19,20] Contusions and abrasions were also common (13% to 16%), as were general soreness and knee pain (14% to 17%). General knee pain has been found to arise from knee-straining work, but older age, overweight, and previous knee injuries are also risk factors.[21] The cumulative effects of

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occupational knee strain over a worker's career also places men and women at increased risk of osteoarthritis.[22]

Data clearly suggest that the risk and burden of occupational knee injuries are high and that these injuries may have long-term adverse effects. Yet, information is sparse about knee injuries across all employee groups and about injuries not involving DAFW and/or injuries with medical costs paid by sources other than workers' compensation. For example, the BLS SOII data are based on employer reports. In 2007, the SOII accounted for injuries only among an estimated 73% of FTE workers in the US labor force.* At that time, the SOII excluded government workers, self-employed workers, persons working for private households, and workers on farms with fewer than 11 employees.† Also, the SOII provides detailed case information for only DAFW cases—29% of the SOII total recordable cases in 2007.[23] Finally, the SOII is impacted by underreporting of occupational injuries.[24]

Although most US workers are covered by workers' compensation insurance,[25] including most of the injured workers captured in the SOII, their SOII-reportable injuries may not have been compensable under each state's workers' compensation regulations and workers may not have filed claims. A 2007 survey in 10 states indicated that workers' compensation paid medical claims for only 47% to 77% of the injured workers.[26] Hence, knee injury profiles derived from the SOII data and workers' compensation claims such as from Washington and Ohio each provide a unique injury perspective.

To provide an additional perspective and address some of the gaps, we used the National Electronic Injury Surveillance System–occupational supplement (NEISS-Work) to describe work-related knee injuries treated in hospital EDs. The National Electronic Injury Surveillance System–occupational supplement does not have inherent employment or medical payer restrictions.[27] Nevertheless, NEISS-Work only accounts for nonfatal occupational injuries and illnesses treated in US hospital EDs—crudely estimated to be 34% of occupational cases requiring medical treatment.[28] National occupational injury data from other medical settings are not generally available. In this study, we describe worker demographics, nature of the injury, and injury circumstances for occupational knee injuries treated in US EDs in 2007 and trends in ED-treated knee injury incidence rates from 1998 through 2007.

MATERIALS AND METHODS

Data Source

We obtained national estimates of work-related knee injuries along with all injuries from 1998 to 2007 through NEISS-Work under a data-use agreement with NIOSH. NIOSH maintains NEISS-Work to collect data on ED-treated work-related injuries and illnesses from a geographically stratified probability sample of 67 US hospitals having a 24-hour ED.[27] Each case is assigned a probability weight based on the treating hospital's assigned stratum to appropriately account for variability in hospital size and the probability of selection to be nationally representative. We calculated national estimates of the number of injuries by summing the individual case weights. Because 90% to 95% of NEISS-Work cases are injuries, with the rest being illnesses, for simplification, we refer to all cases in this study as injuries only.[27]

For NEISS-Work, a *work-related case* is defined as any injury incurred by a civilian noninstitutionalized worker who was working for pay or other compensation, doing agricultural production activities, or working as a volunteer for an organized group.[27] Work-related cases were identified from admission information and ED chart review by hospital records abstractors. The NEISS-Work database includes demographics of injured workers, a short narrative description of the injury, body part involved, diagnosis, event or exposure, source of the injury, disposition from ED, and employment information. We used the NEISS-Work "Part of Body Injured" variable to identify knee injuries.

NIOSH used injury narratives and business/employment information captured by the medical records abstracters to uniformly classify injury events and the industry of the injured worker. The event, source, and secondary source were coded by using the BLS Occupational Injury and Illness Classification System.[29] *Event* or *exposure* was defined as the manner in which the injury or illness was produced or inflicted. *Source of injury* was defined as the object, substance, bodily motion, or exposure that directly produced or inflicted the injury. *Secondary source of injury* was defined as the object, substance, or person that generated the source of the injury or that contributed to the event or exposure. Industry was coded by using the Census Bureau 2002 industry codes.[30] Complete industry coding is available currently for only NEISS-Work 2007 data.

We derived employment estimates from the BLS Current Population Survey of civilian noninstitutionalized workers as FTE workers, where one FTE equals to 2000 hours worked per year.[31] The FTE estimates account for hours worked in all jobs reported to Current Population Survey for workers aged 15 years or older. We calculated the injury rate as the number of injuries per 10,000 FTE workers. Rate estimates by industry were based on FTE in the Current Population Survey industry assigned for a worker's primary job only.

We crudely estimated total occupational knee injuries requiring medical treatment by extrapolating the NEISS-Work ED-treated knee injury estimate by assuming that (1) the same proportion of knee injuries are treated in EDs as are all work-related injuries and (2) 34% of all work-related injuries are treated in an ED.[28] Somewhat similarly, we crudely extrapolated the SOII estimate for knee injuries involving DAFW in 2007 to all occupational knee injuries by using total reportable case and DAFW case data for 2007[32,33] and 2008.[34–37] For this extrapolation, we assumed that (1) for private industry and state/local government workers, the proportions of knee injuries among total injuries were equal to the proportions of DAFW knee injuries among all DAFW injuries; (2) for 2007, the number of total reportable cases and cases of DAFW knee injury for state and local government workers were proportional to 2008 results*; and (3) that private industry and state/local government workers represented 86% of the total employed labor force in 2007.†

Statistical Analysis

The rate ratios with confidence intervals were calculated by using aggregated data for 1998 to 2007. The rate ratio variance was approximated by summing the variance for the individual rates composing the ratio.

We used a negative binomial regression model to assess injury trends by sex and age from 1998 to 2007. To account for the error in the annual rate values when building the regression model, we used a crude approximation based on using the upper and lower 98% confidence bounds for individual years as regression points. We fitted individual models on the basis of the injury rate data stratified by sex, age group, and year to determine whether the injury trends were significant over years, between the sexes, or among age groups. All statistical tests were two-sided with a 5% level of significance. We

*Percentages were derived from the BLS Current Population Survey and the Quarterly Census of Employment and Wages FTE estimates for 2007 (NIOSH unpublished data).
†The SOII excluded federal, state, and local government workers on a national basis before 2008. Beginning in 2008, national estimates for state and local government workers' injuries became available, although federal workers' injuries are still not reported.

*National SOII data for state and local government workers are not available for 2007. To account for higher injury rates among state and local government workers compared with private industry workers, the 2008 proportion of DAFW knee injuries to DAFW total injuries and the total number of reportable cases for state and local government workers were used to adjust the 2007 data by assuming that various proportions were equal for 2007 and 2008.
†See the first footnote (*).

used SAS® (Release 9.2 TS1M0; SAS Institute, Inc, Cary, NC) for statistical analyses.

RESULTS

Characteristics of Work-Related Knee Injuries, 2007

In 2007, there were an estimated 3.4 million (±0.9 million [95% confidence interval]) occupational injuries treated in US hospital EDs. The overall injury rate was 237 (±60) incidents per 10,000 FTE workers. Among these injuries, upper extremities were most commonly injured (41%), followed by the trunk/pubic region (20%), lower extremities (18%), head/neck (18%), and other body parts (4%). Knee injuries accounted for 5% of all injuries. A similar proportion was found for several other joint injuries involving the shoulder (5%), ankle (4%), and wrist (4%). Knee injuries were less common than finger (18%) and hand (8%) injuries and more frequent than elbow (2%) injuries.

There were 184,300 (±54,000) knee injuries at a rate of 13 (±4) per 10,000 FTE workers (Table 1). Men accounted for 60% of knee injuries, but men and women had knee injury rates that were statistically similar (Table 1). Although workers aged 15 to 19 years accounted for only 4% of all knee injuries, men and women in this age group had the highest knee injury rates (men, 23 (±9) and women, 15 (±5), per 10,000 FTE workers). Among men, knee injury rates decreased with increasing age to 8 (±3) per 10,000 FTE workers at the age of 50 years or older (Table 1). Whereas for women, younger workers aged 15 to 24 years and older workers aged 50 years or older had similar high injury rates (13 to 15 per 10,000 FTE workers).

The two most common knee injury diagnoses included strains or sprains (46%) and contusions and abrasions (30%) (Table 2). Workers aged 25 to 44 years incurred about half of all knee strains or sprains (51%) and knee contusions and abrasions (49%). Strain or sprain injury rates were highest among workers aged 15 to 24 years and gradually decreased with increasing age (Fig. 1). In contrast, the injury rates of contusions and abrasions were approximately equal across age groups. The vast majority of workers with knee injuries were treated and released. Only 2% of knee injuries resulted in the worker being hospitalized in the same facility or a higher-level trauma hospital (Table 2). Overall, hospitalized workers with all types of injuries accounted for 2% of cases.

The leading event associated with knee injuries involved a fall (38%). Among all fall-related knee injuries, falls on same level (64%) and falls or jumps to lower level (23%) accounted for the most injuries (Table 2). Younger men tended to have the higher rates of fall-related knee injuries than older men, whereas the opposite was true among women (Fig. 2). Bodily reaction and overexertion* (34%) and contact with objects and equipment (19%) were the next most common major event categories after falls. Together, slips and trips without a fall (included in bodily reactions) and falls on the same level accounted for 33% of the knee injuries. As would be expected, 80% of events involving bodily reaction or overexertion resulted in a strain or sprain, but 36% of falls and 16% of contact events resulted in sprains and strains as well (Table 3). Most contact with object/equipment events resulted in contusions, abrasions, and lacerations (75%). Most fractures arose from falls and dislocations from bodily reaction and overexertion events.

Common sources of knee injuries included structures and surfaces (40%); persons, plants, animals, and minerals (34%); parts and materials (5%); and tools, instruments, and equipment (4%) (Table 2). Of these sources, several subcategories stood out: bodily motion or position of injured, ill worker (28% of total knee injuries);

*Event or exposure, "usually nonimpact, in which injury or illness resulted from *free bodily motion, from excessive physical effort, from repetition of a bodily motion, from the assumption of an unnatural position, or from remaining in the same position over a period of time.*"[29]

TABLE 1. Number and Rate* of Nonfatal Work-Related Knee Injuries Treated in Hospital Emergency Departments by Sex and Age Group, 2007

	Men			Women			Total		
	n (95% CI)	% Total	Rate (95% CI)	*n* (95% CI)	% Total	Rate (95% CI)	*n* (95% CI)	% Total	Rate (95% CI)
Total	111,200 (±34,900)	60	13 (±4)	73,000 (±19,500)	40	12 (±3)	184,300 (±54,000)	100	13 (±4)
Age Group, y	Number	% Men	Rate	Number	% Women	Rate	Number	% Total	Rate
15–19	4,700 (±1,800)	4	23 (±9)	2,700 (±900)	4	15 (±5)	7,400 (±2,300)	4	20 (±6)
20–24	14,600 (±6,000)	13	21 (±9)	7,400 (±2,600)	10	13 (±5)	22,100 (±7,800)	12	18 (±6)
25–29	16,000 (±6,600)	14	17 (±7)	7,100 (±3,200)	10	10 (±5)	23,000 (±9,300)	12	14 (±6)
30–34	15,500 (±4,500)	14	17 (±5)	7,100 (±2,900)	10	11 (±5)	22,600 (±7,000)	12	15 (±5)
35–39	17,700 (±6,600)	16	17 (±7)	7,500 (±2,700)	10	11 (±4)	25,300 (±8,600)	14	15 (±5)
40–44	12,900 (±3,600)	12	12 (±3)	7,400 (±2,200)	10	10 (±3)	20,200 (±4,600)	11	11 (±3)
45–49	10,500 (±4,000)	9	10 (±4)	7,800 (±2,400)	11	10 (±3)	18,300 (±5,900)	10	10 (±3)
50–54	8,700 (±2,500)	8	9 (±3)	11,200 (±2,700)	15	15 (±4)	19,800 (±4,600)	11	12 (±3)
55–59	5,500 (±2,000)	5	8 (±3)	7,500 (±3,000)	10	13 (±5)	13,000 (±4,800)	7	10 (±4)
≥60	5,000 (±1,900)	4	8 (±3)	7,500 (±3,100)	10	15 (±6)	12,500 (±4,300)	7	11 (±4)

*Rate: injuries per 10,000 FTE workers for all jobs worked for workers aged 15 years and older; excluding cases with unknown age.
CI, confidence interval; FTE, full-time equivalent; y, years.

TABLE 2. Number of Nonfatal Work-Related Knee Injuries Treated in Hospital Emergency Departments by Selected Diagnosis, Disposition, Injury Event, and Injury Source, 2007

Characteristic	*n* (95% CI)	%
Total	184,300 (±54,000)	100
Diagnosis		
Strain or sprain	84,300 (±30,800)	46
Contusions and abrasions	56,000 (±16,400)	30
Laceration	9,100 (±2,500)	5
Dislocation	5,300 (±2,100)	3
Fracture	5,000 (±1,600)	3
Foreign body	1,600 (±800)	1
Puncture	1,500 (±800)	1
Other*	21,500 (±7,100)	12
Disposition		
Treated and released†	180,600 (±53,600)	98
Hospitalized or transferred‡	3,100 (±1,500)	2
Injury event		
Falls	70,700 (±20,500)	38
Fall on same level	45,500 (±14,100)	25
Fall or jump to lower level	16,600 (±6,000)	9
Fall, unspecified	8,600 (±2,700)	5
Bodily reaction and exertion	62,300 (±20,000)	34
Bodily reaction§	46,900 (±15,700)	25
Slip, trip, loss of balance without a fall	14,100 (±4,800)	8
Overexertion‖	10,500 (±4,400)	6
Contact with objects and equipment	34,100 (±12,000)	19
Assaults and violent acts	6,400 (±2,500)	3
Transportation incidents	3,600 (±1,000)	2
Exposure to harmful substances/environments	1,200 (±600)	1
Nonclassifiable	4,800 (±1,400)	3
Source of knee injury		
Structures and surfaces	74,000 (±22,200)	40
Floors	31,600 (±9,700)	17
Floors, walkways, ground surfaces, unspecified of building	30,000 (±9,200)	16
Persons, plants, animals and minerals	62,400 (±19,200)	34
Bodily motion or position of injured, ill worker	51,700 (±16,500)	28
Person, other than injured or ill worker	6,600 (±2,700)	4
Parts and materials	8,500 (±3,400)	5
Vehicles	7,700 (±2,200)	4
Tools, instruments, and equipment	6,700 (±2,000)	4
Containers	4,600 (±2,300)	2
Furniture and fixtures	3,900 (±1,700)	2
Machinery	3,800 (±1,500)	2

*Includes predominantly general knee pain, effusion, tendonitis, and unspecified knee injuries plus miscellaneous injuries, such as burns, crushes, hematomas, and avulsions.

†Includes those cases treated and released and held for observation (ie, not directly hospitalized or transferred).

‡Includes those cases hospitalized within the same hospital as the emergency department or transferred to another hospital (typically for higher-level or specialized care).

§Results from free bodily motion imposing stress or strain on the knee.

‖Results from excessive physical effort, such as lifting, pulling, or carrying.

¶The object, substance, bodily motion, or exposure that directly produced or inflicted the injury or illness.[29]

CI, confidence interval.

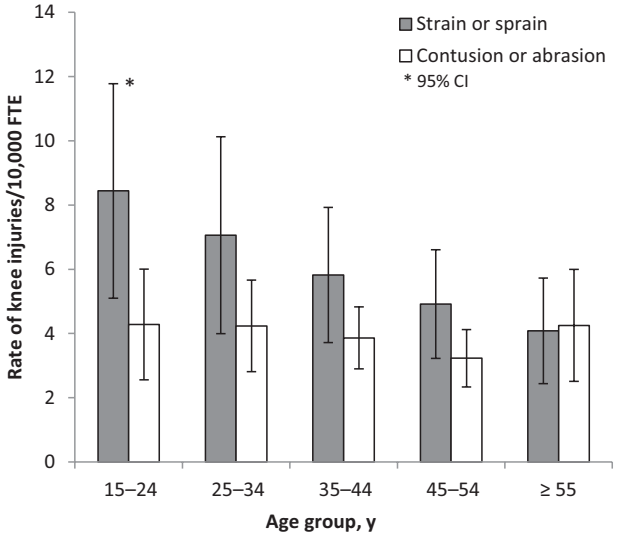

FIGURE 1. Rate of nonfatal strain/sprain and contusion/abrasion work-related knee injuries treated in hospital emergency departments by age, 2007. CI, confidence interval; FTE, full-time equivalent; y, years.

floors (17%); and floors, walkways, ground surfaces, unspecified of building (16%). A secondary source was indicated in 30% of knee injury incidents. The common secondary sources were structures and surfaces such as floors, walkways, and ground surfaces (5% of total knee injuries); tools, instruments, and equipment such as ladders (4%); vehicles such as motorized highway vehicles (4%); persons other than injured or ill worker, plants, animals, and minerals (3%); and containers (2%).

Services industries accounted for one third of the ED-treated occupational knee injuries (Table 4). Within the Services sector, the Health Care and Social Assistance subsector was the largest contributor at 19% of all knee injuries, incurring more knee injuries than any other major Services subsector. Public Administration, which includes law enforcement and firefighting, and Health Care and Social Assistance had the highest rates of knee injuries, followed by the Agriculture and Construction sectors. Men had high injury rates in these same sectors. Women had higher apparent rates than men in the Health Care and Social Assistance and Accommodation and Food Services subsectors, although the differences were not statistically significant.

The total number of occupational knee injuries is not known. Nevertheless, using our estimate of approximately 184,000 ED-treated knee injuries, we crudely extrapolated this ED estimate to knee injuries treated in all types of medical venues. This extrapolation suggests that about 540,000 occupational knee injuries required medical treatment in 2007. Among private industry workers in 2007, the BLS SOII reported that 8% (94,500) of DAFW injuries were knee injuries.[33] Overall in that year, DAFW cases accounted for 29% of the 4 million total reportable cases.[32] By assuming that the proportion of knee injuries among total cases equaled the proportion among DAFW cases, we estimate that private industry workers had about 330,000 knee injuries overall that year. On the basis of further refinement of this estimate to account for injuries of state and local government workers and workers not included in the SOII (see Methods), we extrapolated to a total of 510,000 knee injuries. The two independent extrapolations suggest that US workers incurred on the order of half a million knee injuries in 2007.

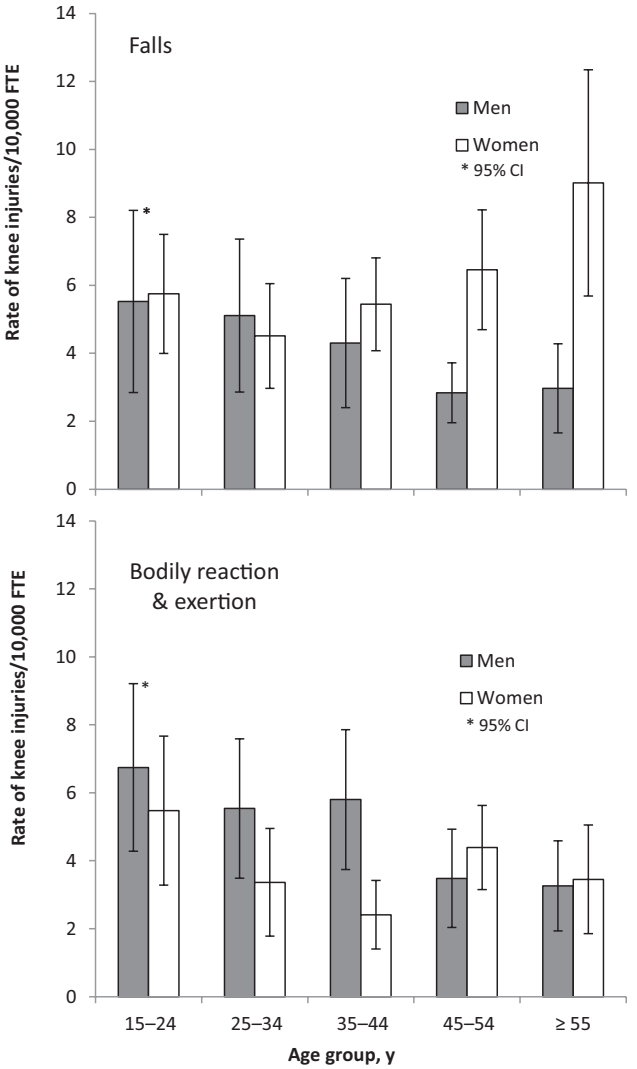

FIGURE 2. Rate of nonfatal fall and bodily reaction/exertion work-related knee injuries treated in hospital emergency departments by age and sex, 2007. CI, confidence interval; FTE, full-time equivalent; y, years.

Trends in Work-Related Knee Injuries, 1998 to 2007

Over the 10-year period from 1998 to 2007, an estimated annual average of 3.6 million (±0.8 million) work-related injuries were treated in US hospital EDs at an average annual injury rate of 270 (±60) injuries per 10,000 FTE workers. During this period, there was an estimated annual average of 198,600 (±50,600) work-related knee injuries at an average annual rate of 15 (±4) knee injuries per 10,000 FTE workers.

Knee injuries were a consistent proportion of all injuries across these years, averaging 5.5% of all work-related injuries (range, 5.2% to 5.8%). Although the proportion of knee injuries stayed constant, from 1998 to 2007, the number of knee injuries declined at an average of 0.3 knee injuries per 10,000 FTE workers per year ($P = 0.02$) (Fig. 3). Knee injuries mimicked the general downward trend observed for all types of work-related injuries across the 10 years. Injury rates for men consistently seemed to be higher than for women, although the men's rate was not statistically higher (rate ratio = 1.2; 95% confidence interval, 0.8 to 1.6).

DISCUSSION

Contrasting the ED-treated, employee-reported data and the SOII employer-reported data offers two national perspectives on occupational knee injuries. For example, we estimate that 184,300 work-related knee injuries (5% of all injuries) were treated in US EDs in 2007 across all industries, employment arrangements, and ages 15 years or older. For the same year, the BLS reported 94,500 knee injuries involving DAFW, 8% of DAFW injuries among private industry workers.[33] When taking into account the system differences, our crude extrapolations suggest that both systems produce relatively similar estimates for total occupational knee injuries—on the order of half a million per year.

Our incidence rates for total, men, and women's knee injuries (13, 13, and 12 incidents per 10,000 FTE workers, respectively) were slightly higher than observed for private industry DAFW cases in 2007 (ie, 10.0, 10.9, and 8.6 for total, men, and women's incidents per 10,000 FTE workers, respectively).[38] The SOII results suggest that men may incur a somewhat higher rate of DAFW knee injuries than women, but a statistically significant sex difference was not found for ED-treated cases independent of age characteristics. The ED data are consistent with workers' compensation observations from West Virginia (a monopolistic state at the time)[39] as well as an electrical utility worker study.[13] Reasons that the SOII may indicate an overall sex rate difference in contrast to the ED results are not clear. It may arise from men doing heavier labor or working in more hazardous jobs in some industries, resulting in more DAFW cases in men than among women.

Younger workers had about twice the rate of ED-treated knee injuries as workers 55 years and older (Table 1). As previously reported for NEISS-Work 2007 data, younger workers, particularly young men, aged 15 to 24 years had higher rates of ED-treated injuries of all kinds.[40] The same factors that generally are thought to contribute to higher overall rates of injuries among younger workers such as lack of job knowledge, skills, and safety awareness[41,42] likely contribute to increased risk of knee injuries among younger workers. Nevertheless, the very nature of jobs in food service, grocery stores, health care, construction, and agriculture[43,44] that many younger workers have expose them to slip, trip, fall, and overexertion hazards that may contribute to higher knee injury risk.

The present ED data also suggest that knee injury rates may increase as women age from their mid-30s to 55 years and older. Among older workers (55 years and older), we found that women had higher knee injury rates than men. Slips, trips, and falls were common among these injured workers. Others have reported that beginning with women aged 50 years (ie, approximate age of menopause), there was a sharp rise in nonoccupational slip, trip, and fall injuries (fracture and nonfracture injuries) in contrast to older men.[45] In that study, deleterious changes in balance, muscle strength, and reaction time were suggested as critical factors for both men and women, but particularly among postmenopausal women who experience a greater rate of change.

In 2007, sprains and strains were the primary diagnoses for ED-treated knee injuries (46%) and for DAFW cases (55%).[46] Contusions and abrasions were more common among the present ED-treated injuries (30%) than among the DAFW cases (14%). General knee pain/soreness (12% to 13%) and fractures (3%) represented about equal proportions of ED-treated and DAFW injuries. Lacerations and punctures accounted for a higher proportion of ED-treated injuries (6%) compared with DAFW cases (2%). The observed differences between ED and SOII results are likely accounted for in the increased proportion of ED-treated contusions/abrasions and lacerations/punctures that would not result in a DAFW and sprains and strains that may have been treated in an outpatient setting instead of the ED.

TABLE 3. Number of Nonfatal Work-Related Knee Injuries Treated in Hospital Emergency Departments by Selected Diagnoses by Leading Injury Events, 2007

	Leading Injury Events, *n* (95% CI)		
Diagnosis	**Fall**	**Bodily Reaction and Exertion**	**Contact With Objects and Equipment**
Sprain or strain	25,500 (±10,100)	49,300 (±17,900)	5,600 (±3,300)
Contusions and abrasions	32,600 (±9,900)	2,300 (±1,400)	15,400 (±5,200)
Laceration	2,800 (±1,200)	—*	6,000 (±2,000)
Dislocation	—	2,900 (±1,200)	—
Fracture	3,200 (±1,400)	—	—
Foreign body	—	—	1,500 (±800)
Other	5,300 (±2,500)	7,000 (±2,800)	—

*Do not meet minimum reporting requirements.
CI, confidence interval.

TABLE 4. Number and Rate of Nonfatal Work-Related Knee Injuries Treated in Hospital Emergency Departments by Major Industry Sectors and Sex, 2007

	Total				
Industry	***n* (95% CI)**	**%**	**Rate (95% CI)***	**Men, Rate (95% CI)**	**Women, Rate (95% CI)**
Agriculture	4,300 (±2,100)	2	19 (±10)	21 (±11)	—†
Mining	—		—	—	—
Construction	19,700 (±8,000)	11	17 (±7)	18 (±7)	—
Manufacturing	15,000 (±5,900)	8	9 (±3)	10 (±4)	5 (±3)
Trade‡	26,100 (±15,700)	14	13 (±8)	15 (±10)	11 (±5)
Transportation, Warehousing, Utilities	11,000 (±3,200)	6	14 (±4)	13 (±4)	16 (±6)
Services	63,400 (±20,000)	34	9 (±3)	6 (±2)	11 (±3)
Management, administrative, waste management services	8,700 (±4,100)	5	14 (±7)	18 (±7)	—
Educational services	8,400 (±4,800)	5	8 (±4)	6 (±4)	9 (±5)
Health care and Social Assistance	35,100 (±10,400)	19	21 (±6)	17 (±8)	22 (±6)
Accommodation and Food Services	11,200 (±3,100)	6	14 (±4)	12 (±5)	16 (±5)
Miscellaneous other services§	12,400 (±4,300)	7	4 (±1)	5 (±2)	3 (±1)
Public Administration	15,400 (±4,600)	8	23 (±7)	27 (±9)	16 (±7)

*Rate: injuries per 10,000 FTE workers for primary job hours only for workers aged 15 years and older; excluding cases with unknown age.
†Do not meet minimum reporting requirements.
‡Includes wholesale and retail trade.
§Includes information, finance, insurance, real estate, rental, leasing, professional, scientific, technical, arts, entertainment, recreation, and other services (except Public Administration).
CI, confidence interval; FTE, full-time equivalent.

The events leading to knee injuries for the present ED-treated and DAFW cases exhibited very similar patterns. Falls accounted for 38% of the knee injuries for both case types (ED and DAFW), with most falls occurring on the same level (64% ED and 72% DAFW).[47] Bodily reaction and exertion led to 34% of ED-treated and 41% of DAFW cases. Three fourths of these cases arose from bodily reactions such as bending, climbing, crawling, reaching, twisting, and slip or trip without a fall. In general, the repetitive nature of these actions is not easily identifiable in source data. For 2007, ED-treated knee injuries involving repetitive motion events did not meet NEISS-Work minimum reporting requirements. The BLS reported fewer than 2% of the DAFW knee injuries involving bodily reaction and exertion resulted from repetitive motion events.[47] Most of the other knee injury events involved contact with objects or equipment (18% to 19% of both case types).

Slips and trips without a fall (8%) and falls on the same level (25%) accounted for one third of the ED-treated knee injuries. Slips and trips have been implicated as common precursors to falls on the same level where various environmental contaminants and other factors play a strong role.[48–50] Slips from floor contamination among food services workers are common.[51–53] During slips, the heel–floor contact usually initiates the slip, but knee flexion plays a critical role in recovery from the slip.[54] Both the initiation and recovery attempt may place significant stress on the knee, whereas the ankle joint is relatively passive. General efforts to address slip, trip, and fall hazards often focus on nonslip shoes, slip-resistant flooring, and

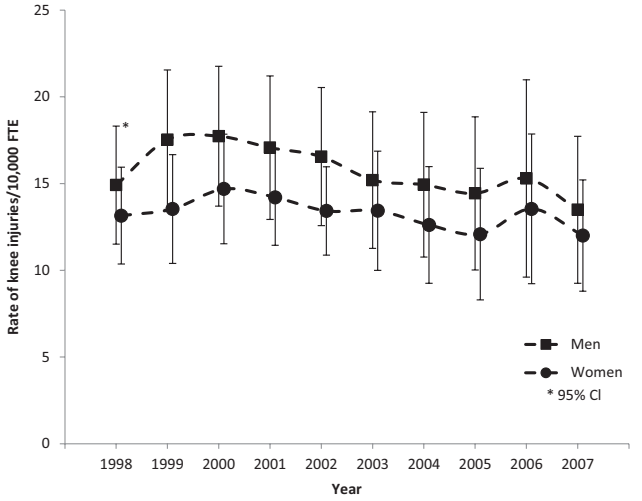

FIGURE 3. Rate of nonfatal work-related knee injuries treated in hospital emergency departments by year and sex, 1998 to 2007 (data points for women are offset for visualization). CI, confidence interval; FTE, full-time equivalent.

removal of floor contaminants.[55] Efforts to reduce muscle fatigue, a potential risk factor for slip-induced falls,[56] may also decrease acute knee injuries.

For knee injuries treated in an ED in 2007, our analysis by industry sector found high rates of knee injuries in the Public Administration sector. In 2010, the SOII local government data indicated that the fire services had the highest knee injury rates within Public Administration.[5] We did not assess knee injuries at this level of industry specificity in this work. We also found high rates in Health Care and Social Assistance, Agriculture, and Construction sectors. The DAFW case data also indicated high knee injury rates for Agriculture and Construction and Transportation and Warehousing.[3] Nevertheless, high knee injury rates for Transportation and Warehousing were not obvious from the ED data. In contrast to the DAFW data, the ED data also indicated a number of Services subsectors such as Management, Administrative, and Waste Management Services and Accommodation and Food Services that had moderately high knee injury rates. The ED data highlight some knee injury differences among ages and sexes that may help target prevention efforts in selected industries, for example, among younger workers and for women within the Services industry subsectors of Health Care and Social Assistance, Accommodation and Food Services, and Educational Services.

Across industries, few knee injury and WMSDs prevention strategies have been evaluated.[57,58] Nevertheless, at least two knee-related work activity or discomfort scales have been developed that help put various work demands or exposures into a formal perspective.[59,60] New tools and working methods for floor layers were found effective at reducing knee strain.[61] Similarly, carpet layers benefited from a redesigned knee kicker.[62] In addition, new knee pad designs that redistribute the pressure at the knee to a greater surface area have been recommended for low seam coal miners.[63] Among assembly plant workers, proper selection of shoes reduced lower extremity fatigue[64]—a risk factor for falls and joint pain. Workplace exercise interventions have not been well studied, but exercise programs among older community members have been shown to improve balance and improve lower extremity strength.[65] Comprehensive occupational fall prevention programs have been effective in reducing slip, trip, and fall claims that account for a high proportion of lower extremity injuries.[66]

"Heavy physical work, prolonged kneeling or squatting, prolonged standing, frequent climbing, and frequent heavy loads lifting and carrying," along with previous knee injury and high body mass index, have been identified as common risk factors for WMSDs involving the knee.[67,68] Knee-bending work activities were specifically identified as a risk for cartilage damage in women that may lead to osteoarthritis, which is commonly more prevalent in women than men.[69] Having a knee injury has been identified as a significant risk factor for osteoarthritic sequelae.[57,59,70,71] Reducing acute occupational knee injuries such as those treated in an ED may moderate such risk. Although osteoarthritis is not commonly compensable under workers' compensation insurance in the United States,[14] many studies have documented the work relationship of osteoarthritis.[22,58,72–76] Nevertheless, ergonomic interventions to reduce knee strain are not widely used across work environments.

Although these NEISS-Work knee injury data may help guide interventions, these data have several limitations. Work-related injuries may not be readily identifiable in the ED records (potentially owing to the worker or health care staff not reporting the work relationship). In addition, non–work-related cases may be misclassified as work-related. Emergency department–treated knee injuries may have unique characteristics compared with knee injuries treated in other medical venues. For example, overuse injuries may be treated more commonly in other outpatient settings. Also, detailed diagnostic and anatomical classifications are not available through NEISS-Work. Complete diagnostic workup of knee injuries may not occur until after the ED records have been abstracted or may occur at a different medical venue. There is often a paucity of information about injury events and patient employment characteristics (eg, occupation)—data seldom required for immediate treatment, but that may guide future prevention efforts. For example, the repetitive nature of work tasks that led to an injury is seldom recorded in the ED data. We found that 2% of the ED-treated knee injuries resulted in immediate hospitalization of the worker. Nevertheless, we could not determine the number of knee injuries that required surgical repair in the days to weeks after the injury. Neither NEISS-Work nor SOII systems account for the long-term sequelae or potential disabilities resulting from occupational knee injuries.

CONCLUSIONS

The NEISS-Work knee injury data suggest that knee injuries have been a consistent fraction of ED-treated occupational injuries for at least a decade, despite recent declines in the number of knee injuries. This is underscored by the relatively high risk among younger workers and the aforementioned increased risk in osteoarthritic sequelae that raises the possibility of long-term reductions in quality of life and capacity to work. In addition, the relatively increased risk of knee injury among older women shows that unique opportunities for prevention present themselves across the work-related life span. Furthermore, our overall estimate of more than half a million work-related knee injuries per year supports the need for a substantial effort to reduce the burden of this problem in the workforce.

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REFERENCES

1. Bureau of Labor Statistics. Nonfatal occupational injuries and illnesses requiring days away from work, 2010 [news release]. Washington, DC: US Department of Labor; USDL 11-1612; November 9, 2011. Available at http://www.bls.gov/news.release/archives/osh2_11092011.pdf. Accessed September 19, 2012.

2. National Safety Council. *Injury Facts*. 2011 ed. Itasca, IL: National Safety Council; 2011.
3. Bureau of Labor Statistics. Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected parts of body affected by injury or illness, private industry, 2010. Washington, DC: US Department of Labor; 2011: Table R6. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2830.pdf. Accessed September 19, 2012.
4. Bureau of Labor Statistics. Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected parts of body affected by injury or illness, state government, 2010. Washington, DC: US Department of Labor; 2011: Table S6. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2946.pdf. Accessed September 19, 2012.
5. Bureau of Labor Statistics. Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by industry and selected parts of body affected by injury or illness, local government, 2010. Washington, DC: US Department of Labor; 2011: Table L6. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb3062.pdf. Accessed September 19, 2012.
6. Lipscomb HJ, Dement JM, Loomis DP, Silverstein B, Kalat J. Surveillance of work-related musculoskeletal injuries among union carpenters. *Am J Ind Med*. 1997;32:629–640.
7. Lipscomb HJ, Schoenfisch AL, Shishlov KS. Non-fatal contact injuries among workers in the construction industry treated in U.S. emergency departments, 1998–2005. *J Safety Res*. 2010;41:191–195.
8. Tak S, Paquet V, Woskie S, Buchholz B, Punnett L. Variability in risk factors for knee injury in construction. *J Occup Environ Hyg*. 2008;6:113–120.
9. Reichard AA, Jackson LL. Occupational injuries among emergency responders. *Am J Ind Med*. 2010;53:1–11.
10. Kim H, Dropkin J, Spaeth K, Smith F, Moline J. Patient handling and musculoskeletal disorders among hospital workers: analysis of 7 years of institutional workers' compensation claims data. *Am J Ind Med*. 2011;55:683–690.
11. Gallagher S, Moore S, Dempsey PG. An analysis of injury claims from low-seam coal mines. *J Safety Res*. 2009;40:233–237.
12. Wiesel SW, Boden SD, Feffer HL. A quality-based protocol for management of musculoskeletal injuries—a ten-year prospective outcome study. *Clin Orthop Relat Res*. 1994;301:164–176.
13. Kelsh MA, Fordyce TA, Lau EC, et al. Factors that distinguish serious versus less severe strain and sprain injuries: an analysis of electric utility workers. *Am J Ind Med*. 2009;52:210–220.
14. Spector JT, Adams D, Silverstein B. Burden of work-related knee disorders in Washington State, 1999 to 2007. *J Occup Environ Med*. 2011;53:537–547.
15. Dunning KK, Davis KG, Cook C, et al. Costs by industry and diagnosis among musculoskeletal claims in a state workers compensation system: 1999–2004. *Am J Ind Med*. 2010;53:276–284.
16. Calmbach WL, Hutchens M. Evaluation of patients presenting with knee pain: part II. Differential diagnosis. *Am Fam Physician.* 2003;68:917–922.
17. O'Keeffe SA, Hogan BA, Eustace SJ, Kavanagh EC. Overuse injuries of the knee. *Magn Reson Imaging Clin N Am*. 2009;17:725–739.
18. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by part of body and selected natures of injury or illness, private industry, 2010. Washington, DC: US Department of Labor; 2011: Table R19. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2843.pdf. Accessed September 19, 2012.
19. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by part of body and selected natures of injury or illness, state government, 2010. Washington, DC: US Department of Labor; 2011: Table S19. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2959.pdf. Accessed September 19, 2012.
20. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by part of body and selected natures of injury or illness, local government, 2010. Washington, DC: US Department of Labor; 2011: Table L19. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb3075.pdf. Accessed September 19, 2012.
21. Miranda H, Viilari-Juntura E, Martikainen R, Riihimaki H. A prospective study on knee pain and its risk factors. *Osteoarthritis Cartilage*. 2002;10:623–630.
22. Andersen S, Thygesen LC, Davidsen M, Helweg-Larsen K. Cumulative years in occupation and the risk of hip or knee osteoarthritis in men and women: a register-based follow-up study. *Occup Environ Med.* 2012;69:325–330.
23. Bureau of Labor Statistics. Workplace injuries and illnesses in 2007 [news release]. Washington, DC: US Department of Labor; USDL 08-1498; October 23, 2008. Available at http://www.bls.gov/iif/oshwc/osh/os/osnr0030.pdf. Accessed September 19, 2012.
24. Ruser JW. Examining evidence on whether BLS undercounts workplace injuries and illnesses. *Mon Labor Rev*. 2008;131:20–32.
25. Sengupta I, Reno V, Burton JF Jr, Baldwin M. *Workers' Compensation: Benefits, Coverage, and Costs, 2010*. Washington, DC: National Academy of Social Insurance; 2012. Available at http://www.nasi.org/sites/default/files/research/NASI_Workers_Comp_2010.pdf. Accessed September 19, 2012.
26. Bonauto DK, Fan JZ, Largo TW, et al. Proportion of workers who were work-injured and payment by workers' compensation systems—10 states, 2007. *MMWR Morb Mortal Wkly Rep*. 2010;59:897–900.
27. Jackson LL. Non-fatal occupational injuries and illnesses treated in hospital emergency departments in the United States. *Inj Prev*. 2001;7(suppl 1):i21–i26.
28. Centers for Disease Control and Prevention. Surveillance for nonfatal occupational injuries treated in hospital emergency departments–United States, 1996. *MMWR Morb Mortal Wkly Rep*. 1998;47:302–306.
29. Bureau of Labor Statistics. *Occupational Injury and Illness Classification Manual*. Washington, DC: US Department of Labor; 2007. Available at http://www.bls.gov/iif/oiics_manual_2007.pdf. Accessed September 19, 2012.
30. US Census Bureau. *Alphabetical Indexes of Industries and Occupations*. Washington, DC: US Census Bureau; 2002. Available at http://www.census.gov/hhes/www/ioindex/. Accessed September 19, 2012.
31. Bureau of Labor Statistics. *Current Population Survey*. Washington, DC: US Department of Labor; 2008: basic monthly microdata files. Available at http://thedataweb.rm.census.gov/ftp/cps_ftp.html. Accessed May 7, 2008.
32. Bureau of Labor Statistics. *Numbers of Nonfatal Occupational Injuries and Illnesses by Industry and Case Types*, 2007. Washington, DC: US Department of Labor; 2008: Table 2. Available at http://www.bls.gov/iif/oshwc/osh/os/ostb1919.pdf. Accessed September 19, 2012.
33. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected parts of body affected by injury or illness, 2007. Washington, DC: US Department of Labor; 2008: Table R2. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb1944.pdf. Accessed September 19, 2012.
34. Bureau of Labor Statistics. Numbers of nonfatal occupational injuries and illnesses by case type and ownership, selected industries, 2008 [news release]. Washington, DC: US Department of Labor; USDL 09-1302; October 29, 2009. Available at http://www.bls.gov/iif/oshwc/osh/os/osnr0032.pdf. Accessed September 19, 2012.
35. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected parts of body affected by injury or illness, 2008. Washington, DC: US Department of Labor; 2009: Table R2. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2084.pdf. Accessed September 19, 2012.
36. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected parts of body affected by injury or illness, state government, 2008. Washington, DC: US Department of Labor; 2009: Table S2. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2214.pdf. Accessed September 19, 2012.
37. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by industry and selected parts of body affected by injury or illness, local government, 2008. Washington, DC: US Department of Labor; 2009: Table L2. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2310.pdf. Accessed September 19, 2012.
38. Bureau of Labor Statistics. Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by part of body affected by the injury or illness and gender, 2007. Washington, DC: US Department of Labor; 2008: Table R105. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb2027.pdf. Accessed September 19, 2012.
39. Islam SS, Velilla AM, Doyle EJ, Ducatman AM. Gender differences in work-related injury/illness: analysis of workers compensation claims. *Am J Ind Med.* 2001;39:84–91.
40. Estes CR, Jackson LL, Castillo DN. Occupational injuries and deaths among younger workers—United States, 1998–2007. *MMWR Morb Mortal Wkly Rep*. 2010;59:449–455.
41. Breslin FC, Day D, Tompa E, et al. Non-agricultural work injuries among youth: a systematic review. *Am J Prev Med*. 2007;32:151–162.
42. Centers for Disease Control and Prevention. *NIOSH Alert: Preventing Deaths, Injuries, and Illnesses of Young Workers*. Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 2003: Publication no. 2003-128. Available at http://www.cdc.gov/niosh/docs/2003-128/pdfs/2003128.pdf. Accessed September 19, 2012.
43. Mardis AL, Pratt SG. Nonfatal injuries to young workers in the retail trades and service industries in 1998. *J Occup Environ Med*. 2003;45:316–323.

44. Occupational Health Surveillance Program. Teens at work: work-related injuries to teens in Massachusetts, 2005–2009. Boston, MA: Massachusetts Department of Public Health; 2012 : Injury surveillance update. Available at http://www.mass.gov/eohhs/docs/dph/occupational-health/injuries/teen-surveillance-update-12.pdf. Accessed October 8, 2012.
45. Davies JC, Manning DP, Kemp GJ, Frostick SP. The rising number of underfoot accidents after the menopause causes both fractures and non-fracture injuries. *QJM*. 2001;94:699–707
46. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by part of body and selected natures of injury or illness, 2007. Washington, DC: US Department of Labor; 2009: Table R19. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb1961.pdf. Accessed September 19, 2012.
47. Bureau of Labor Statistics. Number of nonfatal occupational injuries and illnesses involving days away from work by event or exposure leading to injury or illness and selected part of body affected by injury or illness, 2007. Washington, DC: US Department of Labor; 2009: Table R32. Available at http://www.bls.gov/iif/oshwc/osh/case/ostb1974.pdf. Accessed September 19, 2012.
48. Lipscomb HJ, Glazner JE, Bondy J, Guarini K, Lezotte D. Injuries from slips and trips in construction. *Appl Ergon*. 2006;37:267–274.
49. Courtney TK, Sorock GS, Manning DP, Collins JW, Holbein-Jenny MA. Occupational slip, trip, and fall-related injuries—can the contribution of slipperiness be isolated? *Ergonomics*. 2001;44:1118–1137.
50. Layne LA, Pollack KM. Nonfatal occupational injuries from slips, trips, and falls among older workers treated in hospital emergency departments, United States 1998. *Am J Ind Med*. 2004;46:32–41.
51. Hendricks KJ, Layne LA. Adolescent occupational Injuries in fast food restaurants: an examination of the problem from a national perspective. *J Occup Environ Med*. 1999;41:1146—1153.
52. Courtney TK, Verma SK, Huang YH, Chang WR, Li KW, Filiaggi AJ. Factors associated with worker slipping in limited service restaurants. *Inj Prev*. 2010;16:36–41.
53. Verma SK, Lombardi DA, Chang WR, et al. Rushing, distraction, walking on contaminated floors and risk of slipping in limited-service restaurants: a case crossover study. *Occup Environ Med*. 2011;68:578–581.
54. Cham R, Redfern MS. Lower extremity corrective reactions to slip events. *J Biomech.* 2001:34:1439–1445.
55. Verma SK, Chang WR, Courtney TK, et al. A prospective study of floor surface, shoes, floor cleaning and slipping in US limited-service restaurant workers. *Occup Environ Med*. 2011;68:279–285.
56. Parijat P, Lockhart TE. Effects of lower extremity muscle fatigue on the outcomes of slip-induced falls. *Ergonomics* 2008;51:1873–1884.
57. Fransen M, Agaliotis M, Bridgett L, Mackey MG. Hip and knee pain: role of occupational factors. *Best Pract Res Clin Rheumatol*. 2011;25:81–101.
58. Palmer KT. Occupational activities and osteoarthritis of the knee. *Br Med Bull*. 2012;102:147–170.
59. Reid CR, Bush PM, Karwowski W, Durrani SK. Occupational postural activity and lower extremity discomfort: a review. *Int J Ind Ergon*. 2010;40:247–256.
60. Styron JF, Singer ME, Barsoum WK. Development of the occupational activities knee scale. *J Knee Surg*. 2010;23:95–102.
61. Jensen LK, Friche C. Implementation of new working methods in the floor-laying trade: long-term effects on knee load and knee complaints. *Am J Ind Med*. 2010;53:615–627.
62. Huang WF, Wu CF. Evaluation of a knee-kicker bumper design for reducing knee morbidity among carpet layers. *Appl Ergon*. 2012;43:850–858.
63. Porter WL, Mayton AG, Moore SM. Pressure distribution on the anatomic landmarks of the knee and the effect of kneepads. *Appl Ergon*. 2010;42:106–113.
64. Gell N, Werner RA, Hartigan A, Wiggermann N, Keyerling WM. Risk factors for lower extremity fatigue among assembly plant workers. *Am J Ind Med*. 2011;54:216–223.
65. Judge JO, Lindsey C, Underwood M, Winsemius D. Balance improvements in older women: effects of exercise training. *Phys Ther*. 1993;73:254–262, 263–265.
66. Bell JL, Collins JW, Wolf L, et al. Evaluation of a comprehensive slip, trip and fall prevention programme for hospital employees. *Ergonomics*. 2008;51:1906–1925.
67. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. *Am J Ind Med*. 2010;53:285–323.
68. Reid CR, Bush PM, Cummings NH, McMullin DL, Durrani SK. A review of occupational knee disorders. *J Occup Rehabil*. 2010;20:489–501.
69. Teichtahl AJ, Wluka AE, Wang Y, et al. Occupational activity is associated with knee cartilage morphology in females. *Maturitas*. 2010;66:72–76.
70. Cooper C, Snow S, McAlindon TE, et al. Risk factors for the incidence and progression of radiographic knee osteoarthritis. *Arthritis Rheum*. 2000;43:995–1000.
71. Muthuri SG, McWilliams DF, Doherty M, Zhang W. History of knee injuries and knee osteoarthritis: a meta-analysis of observational studies. *Osteoarthritis Cartilage*. 2011;19:1286–1293.
72. McMillan G, Nichols L. Osteoarthritis and meniscus disorders of the knee as occupational diseases of miners. *Occup Environ Med*. 2005;62:567–575.
73. Järvholm B, From C, Lewold S, Malchau H, Vingård E. Incidence of surgically treated osteoarthritis in the hip and knee in male construction workers. *Occup Environ Med*. 2008;65:275–278.
74. Seidler A, Bolm-Audorff U, Abolmaali N, Elsner G; Knee Osteoarthritis Study Group. The role of cumulative physical work load in symptomatic knee osteoarthritis—a case–control study in Germany. *J Occup Med Toxicol*. 2008;3:14.
75. Klussman A, Gebhardt H, Nubling M, et al. Individual and occupational risk factors for knee osteoarthritis: results of a case–control study in Germany. *Arthritis Res Ther*. 2010;12:R88.
76. McWilliams DF, Leeb BF, Muthuri SG, Doherty M, Zhang W. Occupational risk factors for osteoarthritis of the knee: a meta-analysis. *Osteoarthritis Cartilage*. 2011;19:829–839.

