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Occupational slip, trip, and fall-related injuries—can the contribution of slipperiness be isolated?

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To determine if the contribution of slipperiness to occupational slip, trip and fall (STF)-related injuries could be isolated from injury surveillance systems in the USA, the UK and Sweden, six governmental systems and one industrial system were consulted. The systems varied in their capture approaches and the degree of documentation of exposure to slipping. The burden of STF-related occupational injury ranged from 20 to 40% of disabling occupational injuries in the developed countries studied. The annual direct cost of fall-related occupational injuries in the USA alone was estimated to be approximately US$6 billion. Slipperiness or slipping were found to contribute to between 40 and 50% of fall-related injuries. Slipperiness was more often a factor in same level falls than in falls to lower levels. The evaluation of the burden of slipperiness was hampered by design limitations in many of the data systems utilized. The resolution of large-scale injury registries should be improved by collecting more detailed incident sequence information to better define the full scope and contribution of slipperiness to occupational STF-related injuries. Such improvements would facilitate the allocation of prevention resources towards reduction of first-event risk factors such as slipping.

1. Introduction

Slip, trip, and fall (STF)-related morbidity and mortality are considerable in many developed countries. In the USA, for example, slips and falls are the second largest source of unintentional injury mortality each year (Fingerhut *et al.* 1998). Overall in 1997 in the USA falls were the leading external cause of medically-attended, non-fatal unintentional injuries with 11.3 million episodes reported at an age-adjusted rate of 43.1 per 1000 persons (Warner *et al.* 2000). Slips and falls were also the leading reason for unintentional injury emergency department visits comprising 21% of such visits (National Safety Council 1998).

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Occupationally, Courtney and Webster (1999) recently reported that in the USA slips and falls are associated with the most severely disabling, sudden-onset occupational injuries including fractures. Leamon and Murphy (1995) estimated that annual, direct, per capita costs of occupational injuries due to slips and falls ranged from US$50 to US$400 per worker depending on the industry group considered. Substantial losses have also been reported in the UK, Finland, and Sweden (Manning 1983, Manning *et al.* 1988, Grönqvist and Roine 1993, National Safety Council 1995, Kemmlert and Lundholm 1998).

It is commonly assumed that slipperiness and slipping are major contributors to the STF injury burden. Across national boundaries, the registries that record injury data often differ substantially in their characteristics, focus, and *raison d'être* making international comparisons difficult (Hagberg *et al.* 1997). However, while the limitations of registry data may not permit direct combination, elements from various sources can be compared to attempt to improve the overall understanding of a workplace hazard such as slipperiness.

The primary purpose of the present paper was to determine if, and to what extent, the contribution of slipperiness and slipping could be isolated in various injury surveillance systems in the USA, the UK and Sweden. To provide the necessary foundation for this analysis, the characteristics of each system are presented along with concise analyses of the frequency and severity of the STF-related occupational injuries captured.

2. An overview of the data sources

Seven injury registries were selected to provide a variety of perspectives for the countries chosen as well as approaches to data collection and reporting. Interest lay in observing the STF problem from several different vantage points. It was believed that this approach would afford opportunities to discern the contribution of slipperiness to the STF burden.

The data are presented in four sections. Section 2 introduces the designs and characteristics of various surveillance systems. Section 3 summarizes the STF injuries in each of the surveillance systems. Section 4 presents the available data on nature of injury with a specific focus on the most disabling injuries from systems offering fatal and non-fatal perspectives on disability (or cost as a surrogate for disability). Finally, section 5 examines the available data related to slipperiness from the systems that supported such an analysis.

2.1. *United States Census of Fatal Occupational Injuries (CFOI)*

The United States Bureau of Labour Statistics (BLS) administers the Census of Fatal Occupational Injuries (CFOI). The CFOI collects information about all fatal work injuries in the USA including those incurred by wage and salary workers in private industry and government, and self-employed workers. This surveillance system has collected occupational fatality data nationwide since 1992 and is considered to be a fairly comprehensive census because it gathers information from multiple sources including death certificates, coroner, medical examiner, and autopsy reports, workers' compensation reports, Occupational Safety and Health Administration (OSHA) reports, motor vehicle crash reports, employer questionnaires, and newspaper articles.

Owing to co-operative agreement restrictions between New York City and the BLS, data from New York City were not included in the analyses of fatal

occupational falls in this report. This explains small differences between totals reported here and totals reported in BLS publications.

Descriptive data on occupational STF-related fatalities were available in the CFOI. The BLS Occupational Injury and Illness Classification Scheme also known as OIICS (USDOL-BLS 1992) is used, and falls are categorized into three major groups. Falls on the same level occur when the point of contact with the source of injury is on the same level or above the surface supporting the injured person. Falls to a lower level occur when the point of contact with the source of injury is below the level of the surface supporting the injured person. Finally, jumps to a lower level occur when the injured person leaps from an elevation voluntarily, even if the jump is to avoid an uncontrolled fall or other injury.

2.2. *US Survey of Occupational Injuries and Illness (SOII)*

The BLS also conducts an annual Survey of Occupational Injuries and Illnesses (SOII). From a sample of roughly 200 000 establishments in private industry, the BLS collects employer injury and illness reports and estimates the overall US occupational injury and illness experience (Murphy *et al*. 1996, USDOL-BLS 1997). Agricultural establishments with fewer than 11 employees, self-employed persons, and federal government employees are excluded from the survey. Workers in state and local governments are not included in national estimates.

Annual data on non-fatal injuries associated with slips, trips and falls became available in 1992 when the BLS introduced an expanded SOII method that collected additional detailed data on non-fatal cases with 1 or more days-away-from-work (DAW) (Courtney and Webster 1999). Like the CFOI, the SOII uses the BLS' OIICS coding approach. Data are available on injuries arising from falls to a lower level, falls on the same level, jumps to lower level, and slips, trips or loss of balance without a fall.

2.3. *US National Electronic Injury Surveillance System (NEISS)*

The National Electronic Injury Surveillance System (NEISS) database is a collaborative project between the National Institute for Occupational Safety and Health (NIOSH) and the Consumer Product Safety Commission (CPSC). Initially designed to collect information on injuries from consumer products, it also collects data for all occupational injuries regardless of the source of injury. NEISS comprises 91 hospitals selected as a stratified probability sample of all hospitals in the USA. Any injury that is determined to be work-related during review of the emergency department (ED) records is included in the data. Each injury case in the sample is assigned a statistical weight based on the hospital's probability of selection and used in extrapolation techniques to calculate national estimates (US Centers for Disease Control and Prevention 1998).

2.4. *Data from a large workers' compensation provider in the USA*

One workers' compensation provider (WCP) in the USA covers approximately 10% of the private insurance market with a wide distribution of coverage nationally. Analyses of WCP claims data have been published previously including Leamon and Murphy (1995), Dempsey and Hashemi (1999), and Murphy and Courtney (2000), which addressed various aspects of STF morbidity. The population of claims includes claims from each state of the USA and the District of Columbia, except the six states with monopolistic, state fund workers' compensation systems: Nevada,

North Dakota, Ohio, Washington, West Virginia, and Wyoming. Claims data for 1996 were retrieved in August 1999, allowing a minimum 2.5 year window for claim cost development. Claims involving falls from height and falls on the same level were identified using antecedent event categories based on a proprietary 'cause' code assigned by the WCP claims department. The characteristics of WCP data are further described in Murphy *et al.* (1996).

2.5. *US National Health Interview Survey (NHIS)*

The National Health Interview Survey (NHIS) is the principal source of information on the health of the civilian population of the USA and is one of the major data collection programs of the National Center for Health Statistics (NCHS). Since 1960, NCHS has utilized the NHIS to monitor trends in illness and disability and to track progress toward achieving national health objectives. NHIS data are collected annually from approximately 43 000 households including about 106 000 persons. The annual response rate of NHIS is greater than 90% of the eligible households in the sample.

In 1997 a substantially revised NHIS was fielded. This revision greatly improved the ability of the NHIS to provide important health information especially for injuries. A major strength of this survey lies in the ability to cross-tabulate occupational injury data by many demographic and socio-economic characteristics. The NHIS is also population-based, and thus can provide data on all persons injured at work regardless of workers' compensation coverage, industry or employment status. The NHIS utilizes the *International Classification of Diseases, 9th Revision, Clinical Modification* for coding injury causes and health outcomes (US Public Health Service and Health Care Financing Administration 1991).

The NHIS covers the civilian non-institutionalized population of the USA living at the time of the interview. However, there are several segments of the population which are not included in the sample or in the estimates from the survey. Exclusions are: patients in long-term care facilities, persons on active duty with the Armed Forces (although their dependents are included), and US nationals living in other countries.

2.6. *UK Health and Safety Statistics*

Employers in the UK are required to report any accidents on their premises that cause absence from work for more than 3 days to the national Health and Safety Executive (HSE). There are three categories of severity that are mutually exclusive: fatal, major, and over 3-day accidents (absence from work for more than 3 days). Major injuries include all fractures and dislocations except those involving fingers, thumbs and toes. They also include hospital admissions of more than 24 h.

Annual statistics issued by HSE provide accident numbers and rates per 100 000 employed (excluding the self-employed) for five main occupational groups (HSE 1999). There are 17 'kinds' of accident including 'slips, trips and falls' which are subdivided into slips, trips and falls on the same level, falls from a height of up to 2 m and falls from over 2 m. All fatal accidents are reported. Accidents involving employees travelling to and from work are not collected in the UK.

2.7. Swedish Information System Occupational Injuries and Diseases (ISA)

The *information system om arbetsskador* (ISA) or information system on occupational injuries and diseases was instituted in 1979 under the authority of the National

Board of Occupational Safety and Health (Andersson and Lagerlof 1983). ISA collects data on occupational accidents and work-related diseases reported under the Work Injury Insurance Act. In Sweden, all economically active persons are insured for occupational injuries. A case is registered in ISA only if the injured person is absent from work for at least one day after the day of the accident. Commuting accidents and self-employed and military populations are included. It is computer-based and registers accidents with a sequential description model allowing several events to be recorded for each accident including the injury event, the contact event and the preceding events (Swedish Work Environment Authority and Statistics Sweden 2000).

3. An examination of the scope of the problem

3.1. *US Census of Fatal Occupational Injuries, 1992–1998*

Over the 7-year period from 1992 to 1998, there were 4507 work-related fatal falls in the USA (excluding New York City). The number of fatal occupational falls steadily increased in the USA from 584 in 1992 to 683 in 1998. Of the 4507 work-related fatal falls that occurred during this period, 3946 (88%) occurred when the worker fell to a lower level, 364 (8%) occurred to workers who fell and struck the surface that was supporting them, 43 (1%) of the workers jumped to their death, and the nature of the fall was not specified in 121 (3%) of the deaths.

The male to female ratio varied by type of fall ranging from about 30 to 1 for falls from ladders and scaffolds to about 1 to 1 for falls on the same level. Figure 1 presents the mortality rates for all occupational falls by age of victim. While workers from 25 to 54 years of age accounted for 65% of fall-related deaths, figure 1 shows that occupational fall mortality rates increased substantially with age peaking in workers 65 years of age and older.

With regard to the 364 fatal 'falls on the same level', 255 (70%) of the fatalities occurred when the worker fell to the floor, walkway, or other surface, 74 (20%) when

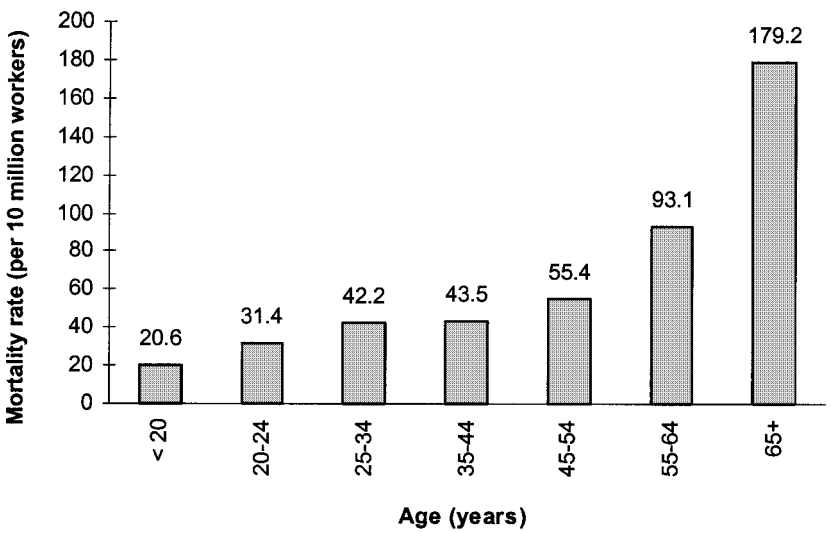

Figure 1. US occupational fall mortality rate by age 1992-1998 (n = 4 507), CFOI.

the worker fell onto or against objects, and in 35 (10%) of the cases the surface or object the worker fell onto was not specified. Common scenarios involved a worker slipping, tripping, or falling and striking their head on a floor, parking lot, concrete, or other rigid surface with sufficient force to cause a fatal brain injury. The incidents where the decedent fell against an object were commonly described as a worker falling against a sharp or pointed object that impaled the worker.

3.2. *US Survey of Occupational Injury and Illness, 1996*

In 1996, the BLS estimated that there were 330 913 non-fatal, fall-related injuries involving 1 or more days away from work (DAW). A total of 30% of these were attributed to falls to a lower level with 66% to falls on the same level, and 4% to jumps to a lower level. The BLS data also indicated that there were an additional 59 328 injuries related to slipping, tripping or loss of balance *without* a resulting fall. These latter injuries comprised 30% of the bodily reaction event category under which they were classified. (Bodily reaction includes slips and trips without falls, but also other injuries due to bodily motion or reaction not involving external objects such as climbing, twisting, running, crawling, etc.). Combining these two estimates provided an estimate of the total burden of disabling occupational STF-related injuries in the USA. Overall, there were an estimated 390 241 disabling STF-related injuries, which accounted for 21% of all disabling injuries reported to the BLS in 1996. STF-related injuries also accounted for 48% of disabling sprains and strains and for 46% of disabling fractures.

Table 1 presents the percentage distribution of fall-related DAW occupational injuries by selected characteristics for 1996. The non-falling injuries noted above were excluded since details were only available at the aggregated bodily reaction category level. Here it may be discerned that while men and women were roughly equivalent in numbers injured in same level falls, men were more likely to be involved in falls to a lower level. Compared to all disabling injuries, disabling fall victims were more likely to be over the age of 55 years. Among industries the Services sector accounted for the largest proportion of STF-related injuries. Interestingly, both falls on the same level and falls from a height had higher median DAW (7 and 10 days, respectively) than the median for all DAW cases (5 days).

3.3. *US National Electronic Injury Surveillance System, 1998*

Data in table 2 are National Electronic Injury Surveillance System (NEISS)-weighted estimates of the number of fall-related occupational injuries treated in US emergency departments in 1998 and were obtained from the National Institute for Occupational Safety and Health, Division of Safety Research, in Morgantown, WV (Jackson and Hixon 2000). The BLS occupational coding scheme (OIICS) was used here as well. The unit of analysis in NEISS was the injury episode not the individual; hence, if someone had two unrelated falls collected in the sample, each incident was counted in table 2.

In 1998 the NEISS-weighted estimates indicated that 550 592 occupational injuries arising from falls were treated in US emergency departments. An additional 49 661 injuries resulted from slips, trips and losses of balance without a fall.

The data suggest a ratio of 2:1 for falls on the same level compared to falls to a lower level. This sample consists of fall events serious enough to warrant a visit to a hospital emergency department. For falls to a lower level and falls on the same level, the trunk, including the shoulder and groin, was injured about as often as the lower

Table 1. Percentage distribution of non-fatal, occupational falls involving days away from work by selected characteristics in the USA, BLS SOII 1996.

Characteristic	All events n = 1 880 525	All falls* n = 330 913	Falls to lower level n = 98 544	Falls on same level n = 219 416
Gender				
Male	65.9	59.7	78.8	49.7
Female	33.0	39.8	20.6	49.8
Age (years)				
14 – 15	0.1	0.3	0.2	0.3
16 – 19	3.9	3.3	2.5	3.7
20 – 24	12.3	9.4	10.6	8.5
25 – 34	29.8	25.3	26.8	24.2
35 – 44	27.2	26.3	27.8	25.8
45 – 54	16.2	20.1	18.1	21.3
55 – 65	6.7	10.8	9.4	11.7
65 or more	0.9	2.1	1.5	2.4
Industry				
Agriculture, forestry, fishing	2.0	2.1	2.9	1.6
Mining	0.8	0.8	1.5	0.5
Construction	9.7	11.5	21.7	6.6
Manufacturing	24.6	16.6	14.8	17.1
Transport, public utilities	11.9	13.0	17.3	11.0
Wholesale trade	7.7	6.3	8.0	5.3
Retail trade	17.1	20.0	11.9	23.8
Finance, insurance, real estate	2.3	3.6	3.7	3.7
Services	23.9	26.0	18.1	30.4
Number of days away				
1	16.7	13.9	11.7	15.0
2	13.1	11.9	11.5	12.1
3 – 5	20.6	18.7	16.9	19.6
6 – 10	13.2	13.1	12.2	13.4
11 – 20	11.7	21.3	12.8	12.1
21 – 30	6.2	6.8	7.0	6.9
31 or more	18.5	23.4	28.0	21.1
Median days away from work	5	7	10	7

* Includes jumps to lower level (approximately 4%).

Table 2. Weighted estimates from NEISS for US emergency department-treated, fall-related, occupational injury events, 1998.

Slip/trip/fall events	Number of injuries	95% confidence interval	Percentage of all STF
Fall on same level	314 027	± 56 315	57
Fall to lower level	164 519	± 29 602	30
Slip/trip without a fall	49 661	± 11 781	9
Jump to a lower level	8 410	± 2 901	2
Unspecified or not elsewhere classified fall	13 975	± 3 641	2
Total	550 592	± 100 066	100

extremities. For slips, trips and losses of balance without a fall, the lower extremities were injured twice as often as the trunk.

3.4. *WCP fall-related claims, 1993–1998*

There were 192 409 claims for injuries due to falls to a lower level from 1993 to 1998. There were an additional 441 745 claims for injuries related to falls on the same level. Same level falls accounted for 70% of the falls claim experience with falls to the lower level comprising 30%. Overall, lower level and same level falls accounted for 5.2% and 12.0% of all workers' compensation claims, respectively, for a combined contribution of 17.2% of all claims filed during the period.

The 634 154 claims filed from 1993 to 1998 accounted for a combined cost of more than US$3.4 billion (25% of all workers' compensation costs). This figure represents the experience of the largest US workers' compensation insurer. From this figure, the direct financial burden of fall-related occupational injuries for the USA over the period was conservatively estimated based on the method of Webster and Snook (1990, 1994) adjusting the cost experience by the company's market share. The total estimate was more than US$37 billion for the entire period or an average of more than US$6 billion annually.

3.5. *US National Health Interview Survey, 1997/1998*

The NHIS questionnaire was administered in person in a house-to-house survey and directly entered into a laptop computer. This method allowed branching of interview questions depending on interviewee responses. The following screening question was used: 'During the past three months, that is 91 days before today's date, were you or anyone in the family injured seriously enough that you/they got medical advice or treatment?'

In 1997 and 1998, the first 2 years of the revised survey, there were an estimated 1 286 180 fall-related injuries at work. A total of 40% of interviewees reporting a fall-related injury reported falling on the same level while 49% reported falling to a lower level, and 11% reported their fall as occurring in some other manner.

3.6. *UK Health and Safety Statistics—STF in Britain excluding Northern Ireland, 1997/98*

Data for STF injuries in mainland Britain for 1997/98 were extracted from the publication *Health and Safety Statistics 1998/9* (HSE 1999). Table 3 presents the calculated incidence of STF accidents by fall type.

Other data reported by the HSE include the number of injuries in each of five main industrial groups: Agriculture, hunting, forestry and fishing; Extractive and utility supply industries; Manufacturing industries; Construction; Service industries. Table 4 shows the numbers of reported accidents and rates per 100 000 employed (excluding self-employed) in the five main industrial groups. The service and manufacturing industries accounted for the highest numbers of major injuries but the highest incidence rates occurred in extractive industries and construction. The HSE statistics do not delineate the numbers of injuries caused by slipping or by tripping because slips, trips and falls are all collected as a single group.

STF accidents were by far the most numerous kind of accident causing major injuries and they were second in rank order of kind of accident causing over 3 days absence in all five industrial groups; only 'injuries whilst handling,

Table 3. The incidence of STF accidents in mainland Britain during 1997/1998, HSE.

	Fatal	Major*	Absent over 3 days	Total
STF on the same level	0	8 671	25 883	34 554
STF from height	64	5 382	8 452	13 898
All kinds of accidents reported to HSE	212	29 187	134 789	164 188
Percentage of all reported accidents				
STF on level	–	29.8%	19.2%	
STF from height	30.2%	18.4%	6.3%	

* Major injuries include all fractures and dislocations except those involving fingers, thumbs and toes. Hospital admissions of more than 24 h are also included.

Table 4. Reported accidents and rates (per 100 000 employed) in the main industrial sectors, HSE.

Industry	Agriculture	Extractive	Manufacturing	Construction	Service
Employment*	300 534	215 035	4 058 866	1 009 598	17 291 483
STF, same level					
Fatal	0	0	0	0	0
Major	118 (39.3)	154 (71.6)	2 008 (49.5)	727 (72.0)	5 664 (32.8)
Absent over 3 days	202 (67.2)	731 (339.4)	6 795 (167.4)	1 615 (160.0)	16 540 (95.7)
STF, from height					
Fatal	4 (1.3)	2 (0.9)	13 (0.3)	29 (2.9)	13 (0.7)
Major	154 (51.2)	108 (50.2)	1 238 (30.5)	1 427 (141.3)	2 455 (14.2)
Absent over 3 days	130 (43.3)	214 (99.5)	2 239 (55.2)	1 213 (120.1)	4 656 (26.9)

*Number employed in each sector. Total employment, excluding the self-employed, was 22 875 516.

lifting or carrying' were a more frequent kind of accident causing absence of over 3 days.

3.7. *Swedish Information System Occupational Injuries and Diseases, 1998*

Sweden's ISA recorded 37 914 occupational accidents resulting in a victim missing at least one day of work in 1998. Included in this figure are injuries to the gainfully employed including those in military service as well as trainees working for no pay. Detailed information was available from the official statistics (Swedish Work Environment Authority and Statistics Sweden 2000) on 35 848 of these cases, which involved employees and self-employed persons. Of these detailed cases, falls accounted for 7 810 accidents (22% of all the accidents) and led all other types as the most common type of occupational accident. Falls to lower levels accounted for 2 609 falls (33% of fall accidents) while falls on the same level contributed 5 201 (67%).

4. Injury severity and disability

Interest next lay in examining severe STF-related injuries to the extent feasible in the available data. Attention focused on fatal injuries and typical, severe, non-fatal injuries (those with the most days away from work and/or highest claims cost).

4.1. *US Census of Fatal Occupational Injury, 1992–1998*

One hundred and ninety-three (53%) of the fatal injuries sustained from 'falls on the same level' were described as blunt trauma to the head that led to fatal brain injuries. Ninety-one (25%) were intracranial injuries, 79 (22%) were multiple intracranial injuries, and 23 (6%) were cerebral haemorrhages. The next highest proportion of fatal injuries were fractures (65, 17.9%), injuries to internal organs (22, 6.0%), and multiple traumatic injuries (15, 4.1%). A total of 32% (n = 116) of the decedents who fell on the same level died on the day of the incident, 232 (64%) survived for 7 days or less, and 33 (9%) of the decedents survived for 98 days or more.

4.2. *US Survey of Occupational Injury and Illness, 1996*

Table 5 describes the 10 most disabling injuries resulting from falls to a lower level and falls on the same level. To enter this table an injury had to have a minimum of at least 500 estimated DAW cases during 1996 (Courtney and Webster, 2001).

4.3. *WCP fall-related severe claims costs, 1993–1998*

For a companion viewpoint to the BLS data on the injuries with the highest median DAW, WCP claims for 1996 were cross-tabulated by body part and nature of injury and then sorted by average expense. Table 6 describes the 10 most costly injuries resulting from falls to a lower level and falls on the same level, respectively. To enter this table an injury type had to have accounted for at least US$500 000 in aggregate costs and have resulted in at least 50 claims filed in 1996. Each injury is ranked

Table 5. Most disabling occupational injuries due to falls to lower level and on the same level in the USA, BLS SOII 1996.

Fall type	Part of body	Nature of injury	Median DAW	Number of cases
To lower level				
	Pelvic region	Fractures	88	762
	Multiple body parts	Fractures and other injuries	63	1 641
	Multiple body parts	Fractures	51	1 046
	Back	Traumatic injuries, unspecified	40	587
	Leg(s)	Traumatic injuries, unspecified	35	551
	Ankle(s)	Fractures	34	3 047
	Shoulder	Nonspecified injuries and disorders	34	593
	Foot (feet), except toe	Fractures	33	2 552
	Leg(s)	Fractures	31	2 103
	Wrist(s)	Fractures	30	3 361
On same level				
	Ankle(s)	Fractures	35	4 056
	Pelvic region	Fractures	32	1 593
	Multiple trunk location	Nonspecified injuries and disorders	32	1 005
	Shoulder	Fractures	32	945
	Shoulder	Traumatic injuries, unspecified	32	694
	Leg(s)	Fractures	29	4 071
	Back	Dislocations	28	919
	Wrist(s)	Fractures	21	5 534
	Multiple body parts	Fractures	21	560
	Hand(s), except finger	Nonspecified injuries and disorders	20	849

according to its ratio against all other claims in its category (to a lower level or on the same level).

In both instances, the injury types presented did not occur with high frequency but did result in substantial disability. If the inclusion criteria based on frequency and total cost used in this analysis were relaxed, less frequently occurring but even more severe injuries would have been presented, in particular those with trauma to the head and spinal cord. These case types would have been similar to the findings for fatal injuries for falls on the same level presented in section 4.1.

5. Contribution of slipperiness

In this section, interest lay in determining if it was possible to isolate or partially isolate the contribution of slipperiness or slipping to the overall burden of STF injuries. This proved to be difficult as slipperiness itself is a difficult concept to track in such large scale systems. However, at least three of the systems provided data in either narrative or coded form relevant to this question.

5.1. *US Census of Fatal Occupational Injury, 1992–1998*

Slipperiness is not tracked in this data system in summary fashion, so it was necessary to examine narratives. To make the examination more manageable, only

Table 6. Most costly occupational injuries due to falls to lower level and on the same level in the USA, WCP 1996.

Fall type	Part of body	Nature of injury	Cost ratio*	Number of cases
To lower level				
	Multiple body parts	Fracture	10.8	762
	Lower leg	Fracture	5.3	110
	Upper arm	Dislocation	3.1	85
	Wrist	Fracture	2.7	287
	Knee	Fracture	2.7	67
	Ankle	Fracture	2.6	366
	Lower arm	Fracture	2.6	122
	Upper arm	Fracture	2.4	83
	Multiple body parts	All other injuries	2.4	1 322
	Foot	Fracture	2.0	316
On same level				
	Disc	Rupture	13.3	99
	Hip	Fracture	5.3	76
	Lower leg	Fracture	4.1	142
	Knee	Fracture	2.7	159
	Knee	Dislocations	2.4	113
	Upper arm	Fracture	1.8	151
	Ankle	Fracture	1.6	591
	Elbow	Fracture	1.6	252
	Hip	Sprain	1.5	66
	Upper arm	Dislocations	1.3	174

*Cost ratio is the ratio of the average cost of the particular injury to the average cost of all injuries for that particular class of falls (e.g. a cost ratio of 5.3 for lower leg fractures means that for claims involving falls to a lower level, those resulting in lower leg fractures cost on average 5.3 times more than the average for all falls to a lower level.

records involving falls on the same level were selected for detailed review. This category was expected to have a higher proportion of fall-related deaths involving slipperiness.

Narrative descriptions of fatal occupational falls on the same level did not provide antecedent information for 169 (approximately 46%) of the incidents. However, for the remaining 195 (54%), a manual review of the narrative descriptions identified the antecedent events for 'falls on the same level'. The worker slipped in 83 (43%) of the incidents, tripped in 35 (18%) of the incidents, lost their balance in 26 (14%), suffered a seizure in 18 (9%), and passed out or fainted in 15 (8%). The remaining 18 cases fell from a chair or stool, fell while snow skiing or ice skating, suffered a fall as a result of a heart attack or as a result of physical combat training. 'Ice, sleet, snow', 'liquids', 'lubricating grease, cutting oils', 'detergent', 'polishes', and 'water' were specifically listed as a secondary source of injury in 14% of all fatal, occupational falls on the same level.

5.2. *US National Health Interview Survey, 1997–1998*

The NHIS asks persons injured at work to attribute the cause of their injury. Table 7 presents weighted and annualized data from 1997 and 1998 for the interviewee-attributed cause of a fall, which resulted in injury at work. The data show that slipping, tripping or stumbling contributed to 64% of all falls, loss of balance to 11%, and jumping or diving to 3%.

5.3. *Swedish Information System Occupational Injuries and Diseases (ISA), 1998*

ISA has a facility to examine events in the causal chain prior to the event to which an injury may be attributed. This has proved to be useful in examining a number of questions using ISA data. Final preceding event data on reported falls in Sweden in 1998 were requested from the Swedish government and are displayed in table 8. The data were obtained from the Swedish Work Environment Authority in Solna, Sweden (Blom 2000). Totals here include 414 cases beyond those published in the official statistics for 1998. These additional cases involved persons in military service, work-related training for no pay, and students.

The 8 224 cases in table 8 do not include cases that involved falling into a tank or pit or jumping to a lower level, which are classified separately from falls to lower levels in ISA. Demonstrating that falls are not the only outcome of concern, there were also 322 cases of overexertion injuries attributed to slipping ($n = 275$) and tripping ($n = 47$), respectively, in 1998.

Table 7. Distribution of causes of all falls at work – NHIS weighted and annualized estimates, 1997/1998.

Causes	Number of events per year	Percentage
Slipping, tripping or stumbling	859 864	64
Loss of balance or dizziness	142 210	11
Jumping or diving	62 044	5
Pushed	35 792	3
Other	235 260	17
Don't know	14 292	1
Total	1 286 180	100

Table 8. ISA fall related injuries by preceding events for 1998.

	Falls on same level		Falls to a lower level	
Preceding events	Number	Percentage	Number	Percentage
Slipping	2 986	55	636	23
Tripping	1 228	22	145	5
Pushed	123	2	45	2
Fainting, tiredness	77	1	17	0.5
Underlay tipped/rolled/slid	96	2	880	32
Vehicle in motion	25	0.5	23	1
Step into the air	249	5	423	15
Lost grip	59	1	94	3
Other fall	627	11	491	18
Totals	5 470	100	2 754	100

The data from table 8 show a 2:1 ratio of falls on the same level to falls to a lower level. Table 8 also demonstrates that the preceding events for falls on the same level and falls to a lower level were different. While slipping was cited in 44% of the 8 224 falls and tripping in 17% of cases, both made a greater proportionate contribution to the same level falls than to falls to a lower level. Falls to a lower level involved a larger percentage of tipped, rolled or slid underlays than falls on the same level (32% vs. 2%). This category relates to the stability of the interface between standing/walking surfaces and supporting surfaces.

6. Discussion

6.1. *STF burden overall*

All the data systems permitted an examination of falls on the same level and falls to a lower level. Regarding these two classes of STF-related injury, it may be readily observed that across these data systems (with one exception of the NHIS) non-fatal falls on the same level consistently outnumbered falls to a lower level by a factor of approximately 2 to 1. This is in contrast to fatal falls where falls to a lower level exceed falls on the same level by a factor of 11 to 1. The NHIS presented the curious result of self-reported falling to a lower level exceeding falls on the same level. Contrasted with the other systems, this may suggest a reduced recall for same level falls and may reflect, in part, a reduced likelihood of seeking medical treatment or advice for these sorts of falls compared with falls from elevation.

Non-fatal falls occurred most frequently in the Services sector. However, fall rates for this sector were the lowest of the five sectors considered in table 4 and highest for the mining and construction sectors.

In Sweden, falls to a lower level and on the same level combined accounted for 22% of disabling accidents. In Great Britain, falls accounted for 30% of all injury events reported to the HSE, a sizeable proportion. While exact matches are not available in the USA, the BLS SOII data indicated that the combined STF category (with non-fall slip and trip injuries included) accounted for 21% of all cases involving a day or more away from work. SOII data further show that nearly one-half of disabling sprains and strains and nearly one-half of disabling fractures are attributable to fall-related events.

6.2. *Injuries among older workers*

Increased fall-related mortality and disability with age were noted in figure 1 and table 1, respectively. These findings are consistent with those of Kemmlert and Lundholm (2001), who recently reported that older workers were more likely to report a greater proportion of STF injuries and to experience higher disability durations. The older worker confronts challenges that can impact susceptibility to work-related injury and disability including changes in body dimension, physiological and sensory capacities, and the ability to adaptively respond to physical stressors (Mital 1994, Laflamme and Menckel 1995).

In the general population, it is estimated that one-third of community-dwelling adults aged 65 years or older fall each year (McElbinney *et al.* 1998). Falls are the leading cause of death from injury in those aged 65 years and older and especially those over 75 years old (Sattin 1992). Approximately 9500 deaths are attributed annually to falls of the elderly in the USA alone. Fall-related mortality in this age group may be related to one of many other contributing factors including co-morbid conditions, *sequelae* of the actual trauma sustained, or nosocomial infections rather than a direct result of the trauma sustained in a fall. As such it is possible that at least some of these injuries are misclassified in existing surveillance systems such as death certifications (Fife 1987).

Kemmlert and Lundholm (2001) reported no differences by age in the exposures contributing to STF injuries and suggested that occupational prevention strategies may not need to differ with age. While it is unclear exactly how the demographic trend of the ageing workforce (Robertson and Tracy 1998, Rantanen 1999) will interact with all these factors, there can be a reasonable expectation that STF-related occupational injuries in older working adults will be one of the expanding challenges in occupational safety in the twenty-first century.

6.3. *Injuries sustained and related disability*

Fatal injuries related to falls often involved head or neck trauma although trauma to internal organs was also a contributing factor. The most disabling non-fatal injuries related to falls were fractures of the pelvis and lower extremities along with some upper extremity fractures and some dislocations. In the USA these most disabling injuries resulted in median absences of as much as 88 days for falls to a lower level and as much as 35 days for falls on the same level (table 5). Courtney and Webster (1999) previously used the data from BLS SOII to examine fractures and reported that falls to a lower level produced the highest median days away from work followed by falls on the same level.

Based on the workers' compensation experience of a large US insurer, the direct insured cost of fall-related occupational morbidity in the USA was estimated at more than US$6 billion annually. Claims for falls to a lower level and falls on the same level combined accounted for 17% of all claims filed and 25% of all claim costs. Leamon and Murphy (1995) studied 278 000 workers' compensation claims from 1989 and 1990 and found that STF represented 16% of all claims and 24% of total claim costs. The present findings suggest that the problem persists.

When costs for the most disabling injuries within a type of fall were considered (table 6), they were found to be as much as 13 times higher than the cost of the average claim for falls to lower levels and as much as 11 times higher for falls on the same level. Higher cost injuries were predominantly fractures and involved the lower extremities, upper extremities and the back.

6.4. *The contribution of slipperiness to STF morbidity and mortality*
Of the data systems consulted only two, the Swedish ISA and the US NHIS, provided any coding to differentiate the contributions of slipping from other types of events in the causal pathway for falls. Descriptive narratives regarding fatal same level falls from the US CFOI were analysed and provided a confirming perspective. Overall in these large data systems there is preliminary evidence that as much as one-half of falls on the same level may be directly attributable to slips. The contribution to falls from height may be more modest based on the ISA data alone at 23% of incidents. The overall ISA finding of slipping contributing to 42% of falling incidents in 1998 is identical to the percentage contribution of slips to falling incidents in Sweden in 1979 as reported by Strandberg (1983).

ISA remains one of the only sources of detailed causal information on large numbers of slipping accidents. However, there are papers in the literature describing studies of accidents that enumerated slips separately from trips and falls. Bentley and Haslam (1998) reported that 42.5% of falls experienced by British mail carriers were the result of slips. Lin and Cohen (1997) reported slips responsible for 13.5% of all injuries. In fast-food outlets Hayes-Lundy *et al.* (1991) reported that 11% of grease burns resulted from slips. Niskanen (1985) reported that slips accounted for 25% of injuries in construction, while McNabb (1994) reported 8% of injuries in petroleum drilling. Shannon and Manning (1980) reported that slipping was the most frequently disabling event resulting in 27% of lost-time injuries in automobile manufacturing.

Ideally, studies and surveillance systems would make use of a detailed method of recording accident data that reflects the sequence of pre-injury or antecedent events. One such system that has been developed and used for this purpose is the Merseyside Accident Information Model (MAIM; Manning 1974). The original concept was described in 1974 and the results of subsequent population-based studies have been published as noted previously (Shannon and Manning 1980, Manning and Ayers 1987, Manning *et al.* 1988, Davies *et al.* 1998, 2001, Manning *et al.* 2000). Currently, MAIM is an intelligent software system designed to collect all available data on injury incidents (Davies and Manning 1994).

The sequence of events, the activities, the human body movements, the environmental objects, the movements and position of the objects and all other contributory factors are addressed as the 'components' in MAIM. However, MAIM's nucleus is the documentation of first unintentional event (first event) in the multi-event incident sequence. For example, a typical event sequence leading to an STF-related injury might include a slip of the foot followed by a loss of balance and then a fall leading to striking the walking surface. Slipping would be recorded as the 'first unintentional event' whereas the fall is recorded as a later event in the timescale of the incident.

6.5. *Limitations of and recommendations for data systems in relation to slipperiness*
Generally, injury surveillance data systems have limitations that should be acknowledged. Owing to resource constraints, many systems have a limited sensitivity for exposure assessment, which proved to be a key factor in the current analysis (Murphy *et al.* 1996, Hagberg *et al.* 1997). The presence of filtering effects at each stage of the reporting process (e.g. a worker's decision to report or an enterprise's decision to report) can also influence what is captured in large-

scale surveillance systems and particularly non-fatal injury systems (Webb *et al.* 1989). Such systems may also be differentially sensitive to various injury and illness types whether planned in design (i.e. hospital trauma surveillance) or unplanned. Finally, most surveillance systems do not collect information on worker experience and socio-economic factors (Cheadle *et al.* 1994, Murphy *et al.* 1996, Hagberg *et al.* 1997, Williams *et al.* 1998, Dassinger *et al.* 1999).

Specific to the issue of STF-related injuries, the majority of data systems consulted could not differentiate slip from non-slip events in fall aetiology. Some like the BLS SOII did document non-fall injuries related to slips but did not isolate the contribution of slipping to fall-related injuries. More often falls were identified according to either the surface the injured fell from or the surface or object onto which they fell. Others like the HSE statistics combined slipping, tripping and falling into one category. Strandberg (1983: 28) commented that 'such single type description models may lead to 'serious underestimates' of the injury contribution from certain events, agencies and activities. In contrast the Swedish ISA permitted examination of the events preceding the actual fall making possible an estimate of the contribution of slipperiness to fall morbidity. Generally, systems like ISA and MAIM, which incorporate the ability to track multiple events in multi-phase incidents will be more successful in correctly attributing STF its proper burden.

There is also growing interest in the use of free text analysis of narrative descriptions of injury incidents provided within some databases to improve the resolution of injury causation (Sorock *et al.* 1997). Previous barriers of storage for such data and the speed with which they can be analysed are dropping rapidly with the gains in technology in recent years. While the success of such approaches relies on the quality and thoroughness of the narrative data collected, such techniques hold promise not only in better describing exposures but also in understanding the events and event-sequencing that precipitated an injury.

As already recognized, STF-related injuries are the results of fairly complex causal pathways in which ultimate causes are often unknown. Therefore, future surveillance research addressing STF-related occupational injuries should attempt to include to the extent possible (in addition to injury details) a description of:

(1) The environmental conditions in the incident scenario: What was the walking surface? Were there contaminants? What were the visual conditions? Was it outdoors or indoors?
(2) The footwear conditions: What type of footwear and sole material? For how long had the footwear been worn?
(3) The human factors in the incident scenario: Was the victim familiar or unfamiliar with the scene of the incident? What was the purposeful activity the victim was engaged in (e.g. walking, running, carrying, or pulling)? Was there anything unusual about the victim's state of mind or health just preceding the incident (e.g. were they tired, rushed, distracted, medicated)?
(4) The time sequence of the incident scenario.

It is recognized that such details may be difficult to obtain, particularly in cases of fatal injury where there were no witnesses. However, where such improvements can be made, significant gains could be achieved in the understanding of the causes of STF-related injuries.

7. Conclusions

The burden of STF-related occupational injury is substantial comprising between 20 to 40% of disabling occupational injuries in the developed countries studied. This percentage increases if more severely disabling injuries are considered especially for falls to a lower level. These proportions may well reflect an underestimate due to peculiarities of the recording of STF-related injuries discussed previously. The estimated annual US direct cost of fall-related occupational injuries alone was approximately US$6 billion with no evidence of a reduction in losses due to slipping and falling over time. Slipperiness or slips were found to contribute to between 40 and 50% of fall-related injuries. Slipperiness was more often a factor in same level falls (as much as 55% of cases) than in falls to lower levels (as little as 23% of cases).

The evaluation of the burden of slipperiness was hampered by design limitations in many of the data systems utilized. Improvements in the resolution of large-scale injury registries by collecting information on incident sequences should be pursued in order to better define the full scope and contribution of slipperiness as a factor in STF-related injuries. A system like ISA or approach like MAIM could serve as a model for such improvements to other systems. Such improvements would facilitate the allocation of prevention resources towards reduction of first event risk factors such as slipping or tripping that may prove more amenable to prevention than falling, particularly on the same level. There are a number of approaches to prevention including improved housekeeping, improved footwear, better design of walking surfaces, control of contaminants, and better work practices outlined in articles such as Leamon (1992) and more recently Bentley and Haslam (2001a, b).

Examining the STF burden almost a decade earlier, Leamon and Murphy (1995) concluded that 'based on the frequency and costs to industry and workers, prevention of falls should be given a high priority'. Despite the evidence presented here, elsewhere in the literature, and the existence of sound literature on prevention, the problem appears to be as pervasive as ever.

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