Using Injury Severity to Improve Occupational Injury Trend Estimates

Jeanne M. Sears, PhD, MS, RN,[1]* **Stephen M. Bowman,** PhD, MHA,[2,3] **and Sheilah Hogg-Johnson,** PhD, MMath[4,5]

Background *Hospitalization-based estimates of trends in injury incidence are also affected by trends in health care practices and payer coverage that may differentially impact minor injuries. This study assessed whether implementing a severity threshold would improve occupational injury surveillance.*

Methods *Hospital discharge data from four states and a national survey were used to identify traumatic injuries (1998–2009). Negative binomial regression was used to model injury trends with/without severity restriction, and to test trend divergence by severity.*

Results *Trend estimates were generally biased downward in the absence of severity restriction, more so for occupational than non-occupational injuries. Restriction to severe injuries provided a markedly different overall picture of trends.*

Conclusions *Severity restriction may improve occupational injury trend estimates by reducing temporal biases such as increasingly restrictive hospital admission practices, constricting workers' compensation coverage, and decreasing identification/reporting of minor work-related injuries. Injury severity measures should be developed for occupational injury surveillance systems.* Am. J. Ind. Med. *© 2014 Wiley Periodicals, Inc.*

KEY WORDS: injury severity; abbreviated injury scale; injury trends; injury surveillance; occupational injuries; hospital discharge data; workers' compensation; occupational health indicator

INTRODUCTION

Occupational injury surveillance involves efforts to accurately characterize trends in the extent and burden of work-related injuries, and is necessary for effective planning and evaluation of prevention efforts. Markedly declining trends in work-related injuries have been reported in recent years [Centers for Disease Control and Prevention, 2007; Council of State and Territorial Epidemiologists (CSTE, 2014); U.S. Department of Labor Bureau of Labor Statistics, 2008]. However, there is also substantial evidence of several barriers to complete surveillance that may have temporal effects, including under-reporting of occupational injuries by workers, employers and health care providers, constricting workers' compensation (WC) coverage, changes in the covered workforce, and changes in employer reporting requirements [Azaroff et al., 2002, 2004; Centers for Disease

[1]Department of Health Services, School of Public Health, University of Washington, Seattle, Washington
[2]Department of Health Policy and Management, College of Public Health, University of Arkansas for Medical Sciences, Little Rock, Arkansas
[3]Center for Injury Research and Policy, Department of Health Policy and Management, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland
[4]Institute for Work and Health, Toronto, Ontario, Canada
[5]Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada
*Correspondence to: Jeanne M. Sears, PhD, MS, RN, Department of Health Services, University of Washington, Box 354809, Seattle, WA 98195. E-mail: jeannes@uw.edu

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Control and Prevention, 2007; Friedman and Forst, 2007a,b; U.S. House of Representatives Committee on Education and Labor, 2008; Sears et al., 2011; Groenewold and Baron, 2013]. Together, these issues cast some doubt on existing estimates of occupational injury rates and trends. Accurate characterization of injury trends is critical to monitoring our state and national progress with regard to occupational injury prevention.

Health care-based surveillance has the potential to more accurately capture trends in work-related injuries than WC or employer-reported data by avoiding some recognized reporting filters [Azaroff et al., 2002], specifically whether a particular injury is recognized and reported as work-related by employers and whether a WC claim is filed and accepted. In addition, some health care databases, trauma registries, and health-related surveys contain a work-relatedness field that is independent of payer. Possibly as a result of these factors, some health care-based studies have painted a less optimistic picture of occupational injury trends than have studies based on WC data or employer surveys. For example, researchers working with the Illinois Trauma Registry found no significant change in occupational traumatic injury rates from 1995 through 2003 [Friedman and Forst, 2007a]. Studies based on data from the National Electronic Injury Surveillance System (NEISS-Work) also did not find evidence of substantial downward trends in injury rates between 1996 and 2005 [Centers for Disease Control and Prevention, 2007; Shishlov et al., 2011]. Yet several studies and a multi-state occupational injury surveillance system have reported declining trends in work-related hospitalizations, using WC as payer to identify work-related injuries [Council of State and Territorial Epidemiologists (CSTE); Dembe et al., 2003; McGreevy et al., 2010].

The current study was motivated by our previous research exploring the Washington State Trauma Registry as a resource for occupational injury surveillance, in which we found a mean annual increase of 5.3% in age-adjusted rates of severe work-related traumatic injury reports from 2003 through 2008 (95% CI: 3.3%, 7.4%), in contrast to approximately flat trends when minor work-related traumatic injury reports were also included (0.9%; 95% CI: −0.7%, 2.4%) [Sears et al., 2011]. The upward trend we observed was robust but unexpected given previous research showing downward or flat trends in work-related injuries in Washington State. According to the employer-based Survey of Occupational Injuries and Illnesses (SOII), there was a nearly monotonic 17% drop in nonfatal injuries from 2003 to 2008 for Washington [U.S. Department of Labor Bureau of Labor Statistics, 2011]. Unpublished data from the Washington State Department of Labor and Industries (L&I) also show a monotonic 17% drop in the number of compensable WC claims during this time period.

A report by the National Center for Health Statistics (NCHS) Expert Group on Injury Severity Measurement provides a potential explanation for these conflicting estimates, stating: "Trends in injury hospitalization discharges and emergency department visits represent a mixture of at least two effects: (1) trends in the incidence of injury; and (2) trends in service utilization and service delivery. Because both can vary over time…the incidence of injury would be better reflected by an indicator of the injury (e.g., injuries meeting a severity threshold) that is 'free' of extraneous factors like utilization and service delivery" [National Center for Health Statistics (NCHS) Expert Group on Injury Severity Measurement, 2004]. This statement is supported by several studies focused on the rising incidence of severe (relative to minor) traumatic brain injury hospitalizations, wherein the researchers concluded that decreasing trends for minor traumatic brain injury were more likely related to changes in hospital practices and probability of admission than to population incidence [Thurman and Guerrero, 1999; Stephenson et al., 2005; Colantonio et al., 2009].

The potential importance of severity restriction to occupational injury surveillance has not been systematically investigated. However, severity restriction, or use of a severity threshold, has been discussed in the more general injury literature as an approach designed to mitigate the impact of changing utilization and service delivery patterns on observed injury trends [Cryer et al., 1999; Cryer et al., 2002; Cryer and Langley, 2008]. Minor injuries may increasingly have been treated in outpatient settings over time [Thurman and Guerrero, 1999; Stephenson et al., 2005]. In addition, changes such as greater stringency in provision of WC benefits, tightening of compensability rules, and increasing pressure against reporting work-related injuries may increasingly reduce capture of minor injuries but have little effect on severe injuries [Langley et al., 2003; Azaroff et al., 2004; Guo and Burton, 2010; Groenewold and Baron, 2013]. Such changes could create a false impression of declining trends in occupational injury burden. Inadequate severity measurement coupled with increasingly incomplete reporting or capture of minor work-related injuries may be a critically important issue affecting estimates of work-related injury trends in many surveillance efforts, and may be contributing to an unwarranted optimism about overall trends in work-related injury rates [Azaroff et al., 2002; Morse et al., 2005; Friedman and Forst, 2007b; Cryer and Langley, 2008].

The objective of this study was to assess whether trend estimates for severe occupational injury hospitalizations differed from those for minor occupational injury hospitalizations. We hypothesized that trends in occupational injury-related hospital discharges would be biased downward in the absence of implementing a severity restriction, due to changing hospitalization and payer practices that may differentially impact minor injuries.

MATERIALS AND METHODS

Data Sources and Study Population

Five distinct population-based data sets were used for this study, including the National Hospital Discharge Survey (NHDS) and four state hospital discharge databases (Arizona, Florida, New Jersey, and Washington). The Washington State Institutional Review Board approved this study. The NHDS is a freely available public use national probability sample of hospital discharges, available from the National Center for Health Statistics [Dennison and Pokras, 2000]. Hospital discharge data for Arizona, Florida, and New Jersey were obtained from the Healthcare Cost & Utilization Project (HCUP), Agency for Healthcare Research and Quality [HCUP State Inpatient Databases (SID), 1998–2009]. Hospital discharge records for Washington State were obtained from the Comprehensive Hospital Abstract Reporting System (CHARS). The SID and CHARS databases contain nearly all community hospital discharges for the respective states, which can be combined with population denominators to produce injury-related discharge rates. The four states were selected to represent diverse geographic areas and different WC systems. Washington has an exclusive WC state fund and no private WC insurers, Arizona has both a non-exclusive WC state fund and private WC insurers, while Florida and New Jersey have only private WC insurers and no WC state fund. These four states satisfied several selection criteria including: (1) data available for all years from 1998 through 2009; (2) at least one level I trauma center to decrease the likelihood that the most severe trauma cases would be hospitalized in a different state; (3) existence of a payer category specific to WC; and (4) external cause of injury codes (E-codes) present for most injuries (e.g., injury E-code presence in 2001: Arizona = 79%, Florida = 80%, New Jersey = 99%, Washington = 97%) [Barrett and Steiner, 2010].

Traumatic injury hospitalizations were included in this study if hospital discharge occurred from 1998 through 2009 (E-codes were often missing for hospital discharge data prior to 1998 [Bowman et al., 2011]). Traumatic injury hospitalizations were excluded for people residing outside the state in which they were hospitalized, to ensure applicability of denominators. We restricted the age range to ages 16 through 64, in order to make the occupational and non-occupational injury groups more comparable, and to minimize secular trends related to Medicare coverage that would be extraneous to this study. Prior to this restriction, those ages 65 and over comprised under 10% of the occupational injury discharges (range for the five data sources: 4–8%) but roughly half of the non-occupational injury discharges (45–57%).

Traumatic injuries were defined using the ICD-9-CM diagnostic codes specified by the National Trauma Data Bank [National Trauma Data Bank, 2011]. This allowed for a standard definition across data sets and ensured that superficial injuries incidental to admission did not result in inclusion. The definition required a first-listed injury diagnostic code in the range 800–959.9, excluding the following injuries: 905–909.9 (late effects of injury), 910–924.9 (superficial injuries, including blisters, contusions, abrasions, insect bites), and 930–939.9 (foreign bodies). Burns (940–949.9) were excluded because the injury severity scoring system we used does not reliably classify burns due to the importance of inhalation injuries (see the Measures section below). Inclusion was based only on the first-listed diagnosis, in order to avoid temporal bias due to the increasing number of available ICD-9-CM codes over time and to ensure that incidental superficial injuries didn't result in inclusion. This comports with injury surveillance recommendations promulgated by the Safe States Alliance (formerly STIPDA) and the Centers for Disease Control and Prevention (CDC) [STIPDA: Injury Surveillance Workgroup 5, 2007; Thomas and Johnson, 2012].

Measures

Work-related injuries were identified as those having WC listed as primary expected payer. The Council of State and Territorial Epidemiologists (CSTE) states that "designation of WC as primary payer is a good proxy for the work-relatedness of hospitalized injuries" [Council of State and Territorial Epidemiologists (CSTE), 2013]. A study based on New Jersey hospital discharge records found that although WC as payer underestimated the number of work-related injuries by about 20%, it was a good to excellent proxy for self-reported work-relatedness (Kappa = 0.78; sensitivity = 83%; specificity = 98%) [Sorock et al., 1993]. In previous work linking Washington State Trauma Registry reports to WC claims, we found that WC as payer was 89% sensitive and 98% specific in identifying injuries resulting in an accepted WC claim [Sears et al., 2012]. In addition, the fact that WC is identified as the expected payer does not necessarily mean that a claim will be filed or accepted; thus expected payer should be somewhat more sensitive than actual payer [Bunn et al., 2007]. Because our interest lies more in assessing differences in trends by severity rather than in quantifying absolute rates or trends, payer should constitute an adequate proxy. There was an additional complication unique to Washington in that WC as payer can indicate either a WC claim *or* a (non-occupational) crime victim claim. Therefore, as a sensitivity analysis, we excluded injuries with any homicide/assault-related E-codes (defined below) from the all-injury analysis to minimize the inclusion of crime victim claims. In our previous research using trauma registry records linked to WC claims, we found that this excluded more than half of injury reports that listed WC as payer but *were not* otherwise identified as work-related, while only excluding about 1% of reports that listed WC as payer and that *were* otherwise identified as work-related [Sears et al., 2012].

External cause of injury codes (E-codes) were used to identify three injury causes of special interest to occupational injury surveillance for trend analysis: (1) fall-related hospitalizations; (2) motor vehicle traffic hospitalizations; and (3) machinery-related hospitalizations. These analyses were restricted to the four state data sets, as the NHDS only had E-codes available for about 70% of work-related injuries and resulting cell sizes were too small to meet NHDS reliability guidelines [Dennison and Pokras, 2000]. Definitions for falls and motor vehicle traffic-related injuries were derived from the definitions described in the 2010 CDC instructions for state injury indicators, using the first-listed valid E-code [Thomas and Johnson, 2012]. An E-code in the range E81X was used to identify motor vehicle traffic hospitalizations (modeled on the CDC instructions for Motor Vehicle Indicator 2). An E-code in the range E880.X-E888.X, excluding E887.X, was used to identify fall-related hospitalizations (modeled on the CDC instructions for Fall Indicator 2). An E-code in the range E919.X was used to identify machinery-related hospitalizations. There is no related state injury indicator, but the machinery category is defined in the STIPDA Consensus Recommendations [STIPDA: Injury Surveillance Workgroup 5, 2007].

The Abbreviated Injury Scale (AIS) was used to measure injury severity for this study [Association for the Advancement of Automotive Medicine, 1990]. AIS is an anatomically-based consensus-driven scoring system that rates injury severity based on threat to life and does not take comorbidity or complications into account. This type of severity score provides a "clean" measure of initial injury severity, independent of patient-specific factors that may influence hospitalization. In particular, AIS provides more face validity and empirical support as a measure of initial injury severity than do hospital admission or length of stay, both of which can be related to co-existing conditions, health status, and trends in insurance coverage and standards of care [Stephenson et al., 2005; Cryer et al., 2010; Cryer and Langley, 2008; National Center for Health Statistics (NCHS) Expert Group on Injury Severity Measurement, 2004]. AIS-based injury severity scores have been validated for prediction of mortality [Baker et al., 1974; Osler et al., 1997; Meredith et al., 2002; Kilgo et al., 2003; Harwood et al., 2006], and recent studies have established their association with occupational injury outcomes such as work disability and medical costs [Ruestow and Friedman, 2013; Sears et al., 2013a].

AIS was estimated from the first-listed ICD-9-CM diagnosis code using -icdpic-, a Stata user-written program developed using National Trauma Data Bank (NTDB) data [Clark et al., 2010]. The most serious injury, usually listed first if the primary reason for admission, has been found to predict mortality as well as all injuries [Kilgo et al., 2003]. The -icdpic- program contains a crosswalk from ICD-9-CM diagnosis codes to AIS severity. Burns were excluded from this study because AIS does not reliably classify burns due to the importance of inhalation injuries (inhalation injuries are not scored by AIS), and -icdpic- does not score burns. The AIS ordinal scale ranges from 1 (minor) to 6 (maximal). For this study, we defined severe injury as an AIS of 3 (serious) or above; these injuries carry a high probability of hospital admission and thus the hypothesized effect of systematic reductions over time in hospitalized injury ascertainment due to secular trends in hospital admission practices should be minimized for this subset [Cryer and Langley, 2008]. To illustrate the severity threshold we used, the ICD-9-CM code 821.0 (closed femur shaft fracture) maps to an AIS of 3 (classified as severe for this study), while 824.0 (closed medial malleolus/ankle fracture) maps to an AIS of 2 (classified as minor for this study). As another example, 887.0 (uncomplicated below-elbow amputation of arm/hand) maps to an AIS of 3, while 885.0 (uncomplicated thumb amputation) maps to an AIS of 2.

Data Analysis

Rates of work-related traumatic injuries were based on employed population denominators obtained from the Bureau of Labor Statistics' Current Population Survey (CPS), as recommended by the CSTE [Council of State and Territorial Epidemiologists (CSTE), 2013]. Denominators for non-work injuries were based on US Census Bureau annual resident population estimates. For NHDS-based analyses, the inflation weights supplied with the files were combined with denominators to produce nationally representative discharge rates.

Negative binomial regression models that included a continuous variable for discharge year and that adjusted for employed population denominators were used to model injury rates and linear trends. Negative binomial regression was used in preference to Poisson models because the Vuong test often indicated overdispersion [Vuong, 1989; Liu and Cela, 2008]. Models were run with and without severity restriction. Temporal trend divergence by severity was tested using an interaction term representing the ratio of the temporal trend for severe injuries to that for minor injuries.

Crude and age-adjusted trends for the period from 1998 through 2009 were calculated for work-related injury hospitalizations overall and for the three injury cause categories. For comparative purposes, the same models were run for non-work injuries. Age adjustment was performed using direct standardization based on the U.S. 2000 Standard Population (ages 16+) [Klein and Schoenborn, 2001] and gamma confidence intervals were calculated [Fay and Feuer, 1997]. In the age-restricted samples used for this study, there were only slight and unremarkable differences between the crude and age-adjusted rates and trends. Age adjustment could not be performed using the NHDS since the small cell size for several of the age strata did not meet NHDS standards for reliability [Dennison and Pokras, 2000], and age adjustment was also problematic for some of the smaller subcategories in the state-based analyses. Therefore, for consistency, crude rates and trends have been presented throughout this manuscript except where otherwise indicated. All statistical tests were two-tailed, with statistical significance defined as $P \leq 0.05$. All analyses were conducted using Stata/SE 11.2 for Windows (StataCorp LP, College Station, TX).

RESULTS

Table I presents the results of the trend models for traumatic injuries having WC listed as the primary payer. The baseline (1998) injury rates provide a rough idea of the size of the three injury cause categories relative to all injuries, the proportion of all injuries that were identified as severe, a general idea of rate variation across the state and national samples, and the amount of injuries covered by WC versus non-WC payers (when compared with Table II). Within the mean annual percent change section of the table, trends based on all injuries can be compared to trends based on just severe injuries. For example, there was an estimated 3.4% mean annual decrease in all NHDS injuries, while the trend for severe NHDS injuries was statistically flat. As shown in the trend interaction columns, severe NHDS injuries trended significantly upward relative to minor NHDS injuries. (Note that this does *not* imply a significantly increasing annual trend for severe injuries; in this analysis, the trend line for severe injuries was compared to the trend line for minor injuries rather than to a flat line.) In every case, the trend line for severe injuries either trended upward relative to minor injuries, or was not statistically different. When we dropped assault-related injuries from the all-injury Washington sample for the sensitivity analysis (because crime victim

TABLE I. Hospital Discharge Rates and Trends for Work-Related Traumatic Injuries, By Severity

	Baseline (1998) injury rate per 100 K employed		Mean annual % change			Interaction (severe trend/minor trend)		
Sample	**All**	**Severe**	**All**	**Severe**	**Minor**	**Trend ratio**	**95% CI**	***P*-value**
All injuries								
National (NHDS)	39.2	6.5	↓3.4*	↑1.5[a]	↓4.9*	1.067	1.023–1.112	0.001
Arizona	43.2	9.2	↓1.4[a]	↑0.4[a]	↓2.0[a]	1.024	0.981–1.069	NS
Age-adjusted	43.5	9.5	↓1.5[a]	0.0[a]	↓2.0[a]	1.020	0.975–1.067	NS
Florida	50.5	12.5	↓4.0*	↓3.5*	↓4.1*	1.007	0.988–1.026	NS
Age-adjusted	50.8	12.8	↓4.2*	↓3.9*	↓4.3*	1.004	0.984–1.024	NS
New Jersey	54.7	7.8	↓4.9*	↓0.5[a]	↓5.9*	1.057	1.033–1.081	<0.0005
Age-adjusted	55.1	8.0	↓5.1*	↓1.0[a]	↓6.1*	1.053	1.029–1.078	<0.0005
Washington	41.5	9.4	↓0.8[a]	↑1.5*	↓1.5*	1.031	1.011–1.050	0.002
Age-adjusted	41.6	9.6	↓0.7[a]	↑1.3[a]	↓1.4*	1.028	1.009–1.046	0.003
Falls								
Arizona	13.9	3.6	↑0.2[a]	↑1.3[a]	↓0.2[a]	1.015	0.968–1.065	NS
Florida	16.0	4.9	↓1.2*	↓1.8[a]	↓1.0[a]	0.992	0.971–1.014	NS
New Jersey	18.7	3.5	↓3.5*	↑0.1[a]	↓4.5*	1.048	1.026–1.071	<0.0005
Washington	16.4	3.9	↓0.5[a]	↑1.6[a]	↓1.2*	1.027	1.004–1.052	0.022
Motor vehicle traffic								
Arizona	4.5	1.4	↓1.3[a]	0.0[a]	↓1.9[a]	1.019	0.956–1.088	NS
Florida	4.9	1.7	↓1.7*	↓0.4[a]	↓2.6*	1.022	0.998–1.046	NS
New Jersey	5.8	1.5	↓3.0*	↓1.0[a]	↓3.8*	1.028	0.995–1.063	NS
Washington	3.5	1.2	↓3.6*	↓2.6[a]	↓4.1*	1.016	0.979–1.054	NS
Machinery								
Arizona	4.7	0.8	↓2.3[a]	↓0.3[a]	↓2.9[a]	1.026	0.966–1.091	NS
Florida	4.8	1.0	↓3.6*	↓3.8*	↓3.6*	0.999	0.969–1.029	NS
New Jersey	7.2	0.9	↓5.2*	↓1.6[a]	↓5.8*	1.041	1.006–1.076	0.02
Washington	6.0	1.5	↓4.0*	↓3.2*	↓4.2*	1.010	0.973–1.048	NS

Note: Crude estimates are shown unless otherwise noted. NHDS, National Hospital Discharge Survey.
*Statistically significant trend (trend not flat, at $P \leq 0.05$).
[a]Not statistically significant.

TABLE II. Hospital Discharge Rates and Trends for Non-WC Traumatic Injuries, By Severity

Sample	Baseline (1998) injury rate per 100 K residents		Mean annual % change			Interaction (severe trend/minor trend)		
	All	Severe	All	Severe	Minor	Trend ratio	95% CI	*P*-value
All injuries								
National (NHDS)	335.0	88.1	↑0.1[a]	↑2.6*	↓0.9*	1.036	1.024–1.047	<0.0005
Arizona	379.2	115.7	0.0[a]	↑1.1[a]	↓0.4[a]	1.015	0.995–1.035	NS
Age-adjusted	378.0	115.7	0.0[a]	↑0.9[a]	↓0.4[a]	1.013	0.993–1.033	NS
Florida	313.0	103.0	↑0.7*	↑1.4*	↑0.3[a]	1.011	1.005–1.018	0.001
Age-adjusted	314.2	103.5	↑0.5*	↑1.1*	↑0.2[a]	1.010	1.003–1.017	0.007
New Jersey	318.0	70.7	↓1.4*	↑1.5*	↓2.5*	1.041	1.030–1.051	<0.0005
Age-adjusted	320.9	71.6	↓1.7*	↑1.1*	↓2.6*	1.038	1.028–1.049	<0.0005
Washington	238.4	71.7	↑0.8*	↑2.1*	↑0.2[a]	1.019	1.010–1.028	<0.0005
Age-adjusted	240.0	72.4	↑0.5[a]	↑1.7*	0.0[a]	1.017	1.007–1.026	<0.0005
Falls								
Arizona	65.3	21.4	↑2.9*	↑3.5*	↑2.6*	1.009	0.984–1.036	NS
Florida	58.3	19.9	↑5.4*	↑6.2*	↑5.0*	1.011	1.001–1.022	0.038
New Jersey	96.4	22.0	↑0.1[a]	↑3.1*	↓0.9[a]	1.041	1.028–1.053	<0.0005
Washington	78.4	21.6	↑1.9*	↑4.0*	↑1.0*	1.030	1.021–1.039	<0.0005
Motor vehicle traffic								
Arizona	119.5	37.2	↓1.2[a]	↑0.5[a]	↓2.1[a]	1.027	0.984–1.071	NS
Florida	94.0	33.7	↑1.2*	↑2.6*	↑0.2[a]	1.024	1.011–1.037	<0.0005
New Jersey	85.9	22.9	↓2.5*	↓0.2[a]	↓3.5*	1.034	1.023–1.044	<0.0005
Washington	71.9	26.3	↓1.7*	↓0.9[a]	↓2.1*	1.013	1.000–1.026	0.042
Machinery								
Arizona	2.3	0.3	↓3.1*	↓6.6*	↓2.6[a]	0.960	0.894–1.030	NS
Florida	2.1	0.2	↓0.1[a]	↑2.3[a]	↓0.4[a]	1.028	0.984–1.074	NS
New Jersey	2.9	0.2	↓2.3*	↑0.3[a]	↓2.5*	1.029	0.977–1.084	NS
Washington	2.1	0.4	↓2.3*	↓9.9*	↓1.4[a]	0.914	0.862–0.969	0.002

Note: Crude estimates are shown unless otherwise noted. WC, workers' compensation; NHDS, National Hospital Discharge Survey.
*Statistically significant trend (trend not flat, at $P \leq 0.05$).
[a]Not statistically significant.

claims cannot be distinguished from WC claims in Washington), the severe/minor interaction remained very similar to the estimate shown in Table I (trend ratio: 1.023; 95% CI: 1.002–1.045; $P = 0.03$).

Figure 1 provides a graphical depiction of national rates and trends for all NHDS work-related traumatic injuries and for the severe subset. Figure 2 provides the same information for the four states in this study. Figure 3 includes the trend lines for all five data sets and samples to visually summarize the impact of severity restriction on observed trends; in other words, the effect of including only the severe subset of work-related traumatic injuries rather than all injuries when assessing temporal trends in occupational injury rates.

Table II presents results of the same analyses presented in Table I, but for injuries that did *not* have WC listed as the primary payer. The injury trends themselves (mean annual percent change) were often quite different than for work-related injuries, as might be expected due to differences in causes and prevention efforts. However, the findings for the severe/minor trend ratios taken as a group provide a roughly similar picture across the two tables. Aside from the machinery category, the trend line for severe injuries always either trended upward relative to minor injuries or was not statistically different, just as for work-related injuries. The machinery-related injury category was distinct in that it was the only injury category in which there was a statistically significant downward trend for severe injuries relative to minor injuries (non-WC injuries in Washington). It was also the only injury category in which there were fewer non-WC injuries than work-related injuries. With Florida as a notable exception, the trend ratio point estimates for work-related injuries were always larger than or very similar to those for non-WC injuries. In contrast, this picture was reversed in Florida.

DISCUSSION

The objective of this study was to assess whether trend estimates for severe occupational injury hospitalizations differed from those for minor occupational injury hospitalizations,

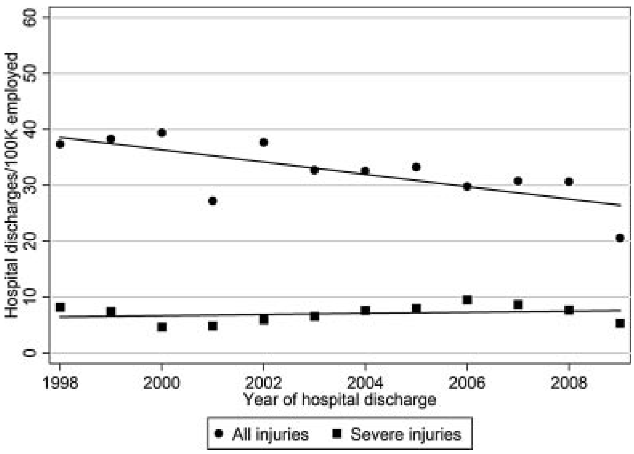

FIGURE 1. National trends for all work-related traumatic injuries and for the severe subset (National Hospital Discharge Survey).

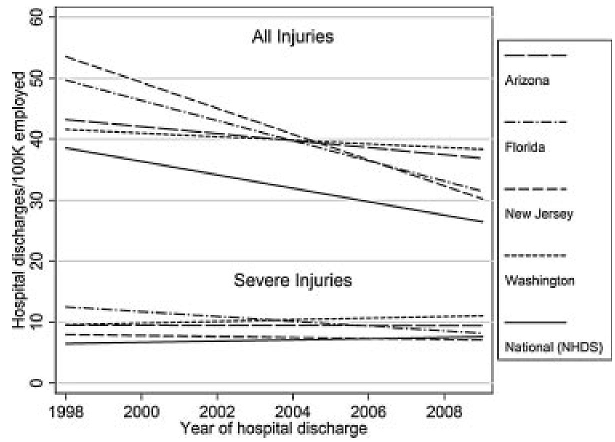

FIGURE 3. Impact of including only the severe subset of work-related traumatic injuries rather than all injuries when assessing temporal trends in occupational injury rates (five population-based data sources).

using several population-based databases, and a novel application of a validated severity measure. In every case, the trend line for severe work-related injuries either trended upward relative to minor injuries, or was not statistically different. The severe/minor trend interaction was used for statistical testing, but it is more practically relevant to compare observed trends for *all* injury hospitalizations (the current surveillance practice) to trends for *severe* injury hospitalizations, as a potential improvement to current surveillance methodology (Figs. 1 and 2). As shown in Figure 3, even though the degree of bias varies by data source, the overall impact of severity restriction on observed trends

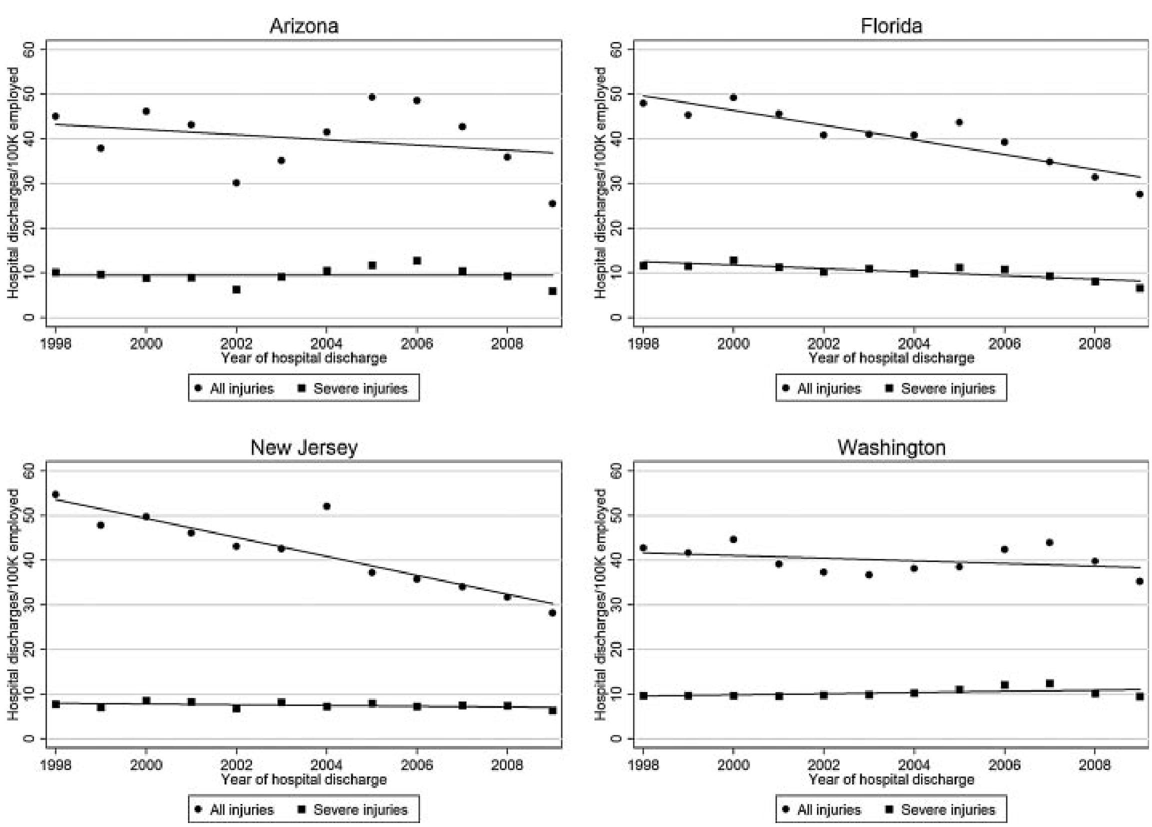

FIGURE 2. State-based trends for all work-related traumatic injuries and for the severe subset.

can be dramatic. This study provided evidence to support our hypothesis that trends in occupational injury-related hospital discharges would be biased downward in the absence of severity restriction, and our findings comport with previous research and conjecture in the more general injury literature [Thurman and Guerrero, 1999; Cryer et al., 1999, 2002; Stephenson et al., 2005; Colantonio et al., 2009; Cryer and Langley, 2008; National Center for Health Statistics (NCHS) Expert Group on Injury Severity Measurement, 2004].

The findings of this study suggest that previously reported downward trajectories in occupational injury trends may have been overstated, in part due to unavailable or inadequate severity measurement in combination with secular trends in the capture of minor injuries. Hospital discharge-based studies and surveillance systems that have reported declining trends in work-related hospitalizations have relied on using WC as payer to identify work-related injuries, and none have controlled for severity [Council of State and Territorial Epidemiologists (CSTE); Dembe et al., 2003; McGreevy et al., 2010]. This study was not designed to identify causes of bias in the absence of severity restriction; however, our findings are consistent with explanations suggested for similar findings in several studies of traumatic brain injury-related hospitalization trends, including changing standards of care that have resulted in decreasing probabilities of hospital admission for minor injuries and a shift from inpatient care to care in emergency departments, observation units, and other outpatient facilities [Thurman and Guerrero, 1999; Stephenson et al., 2005; Colantonio et al., 2009].

A similar effect with respect to the severe/minor trend ratios was observed in the non-WC injury samples. Interestingly, the trend ratio point estimates for work-related injuries were often larger than those for non-WC injuries. This suggests that the severe/minor trend differential may be affected by additional factors specific to work-related injuries, such as constricting WC coverage, workforce changes, increases in contingent or precarious employment over time, and/or decreasing identification or reporting of minor injuries as being work-related (by health care providers or workers) [Azaroff et al., 2002, 2004]. A counter-intuitive and possibly related finding of negative correlation across states between fatal and nonfatal construction sector injuries was described by RAND researchers; proffered explanations included state-level variation in underreporting and WC system practices [Mendeloff and Burns, 2013]. A study using National Hospital Ambulatory Medical Care Survey data from 2003 to 2006 found that an increasing proportion of work-related emergency department visits nationally did not have WC listed as primary payer, though no differential by severity was identified [Groenewold and Baron, 2013]. Decreasing access to health insurance coverage other than WC, as well as adaptation by health care providers to changing economies and financial pressures, may also have an important impact on observed trends in occupational injury rates, especially when using WC as a proxy for work-relatedness [Sears et al., 2013b]. Hospitals have undertaken increasingly intensive efforts to identify potential payers and recoup the costs of care, particularly for the most expensive and severe injuries [Helling et al., 1995; Nahm et al., 2012; Sears et al., 2013b]. The impact of these factors may well vary state-to-state, depending on WC reimbursement rates, WC insurance structure, perceived barriers to claim filing, trends in the proportion of uninsured, etc. Based on the data available to us, we cannot be certain whether some combination of these or other factors may explain the variation in findings among the states in this study, particularly those for Florida. We have no clear hypothesis as to why Florida's results were so distinct; the impact of age adjustment was as unremarkable for Florida as it was for the other three states.

The machinery-related injury category was distinct in that it was the only injury category in which there was a statistically significant downward trend for severe injuries relative to minor injuries (non-WC injuries in Washington). It was also the only injury category in which there were fewer non-WC injuries than work-related injuries. One possible (but highly speculative) interpretation is that there were few enough non-occupational machinery-related injuries to allow for the detection of a crossover effect from non-WC to WC, whereby severe injuries were more likely to be claimed under WC over time (but minor injuries less so). According to Washington State Trauma Registry data, more than two-thirds of machinery-related injuries are work-related (independent of payer), a much higher percentage than for any other injury cause category aside from electrocution [Sears et al., 2012]. It is possible that severe work-related injuries in the machinery category were increasingly likely to be claimed under WC over time, as the percentage of workers otherwise uninsured rose and hospitals increasingly sought to identify potential payers for the most severe injuries. That mechanism would have the effect of increasingly draining the severe non-WC category relative to the minor non-WC category, and could explain the non-WC trend ratio findings for machinery-related injuries in Washington and Arizona (which also happen to be the two state fund states in this study). Confirming such a mechanism would require additional study. On the other hand, there were fewer than 35 severe non-WC machinery-related injuries every year in every state, and hence trend estimates for this category may be unreliable. It is also possible that targeted prevention efforts and/or changing economies may have had some differential effect on machinery-related injuries. Unfortunately, there is no occupation or industry information available in the hospital discharge data that could shed light on possible mechanisms.

Strengths and Limitations

In this study, we used five population-based hospital discharge data sets to confirm our earlier exploratory and somewhat surprising findings using the Washington State Trauma Registry. These data sets were selected a priori to provide strong generalizability, and they include a nationally representative hospital survey, as well as four states representing diverse geographic areas and structurally different WC systems. Given the variation in findings, especially for Florida, extending this study to additional states would be informative. A larger sample of states may clarify whether there are identifiable patterns driving the variation.

Although hospital discharge data bases are population-based, they do carry limitations. Hospital discharge records are only available for non-federal, acute care hospitals. They do not have a work-relatedness field independent of payer, nor do they include occupation or industry information. Use of WC as payer is known to undercount work-related injuries [Sorock et al., 1993; Sears et al., 2012]. In addition, the expected payer on hospital discharge records may not be accurate and may not reflect the actual payer. Patients hospitalized outside their state of residence were excluded. All hospital discharges were counted, including potential readmissions for the same injury.

This study involved methods not typically used for occupational injury surveillance. Two software packages that estimate injury severity directly from ICD-9-CM codes have been used for injury research: (1) ICDMAP-90 software developed by and available from the Johns Hopkins Bloomberg School of Public Health [MacKenzie et al., 1989], and (2) the Stata user-written -icdpic- program used for this project [Clark et al., 2010]. ICDMAP-90 is not current to the most recent ICD-9-CM and AIS changes and does not run on newer computers, while -icdpic- is freely available and easily run by Stata users. Injury severity scores based on -icdpic- are now being included in some hospital discharge files released by HCUP. A small validation study found that -icdpic- did not concord well with injury severity scores assigned by expert trauma personnel [Di Bartolomeo et al., 2010]. However, we have found substantial agreement between injury severity scores estimated by -icdpic-, ICDMAP-90, and trauma registrars [Sears et al., 2014].

One possible competing explanation for our findings is that changes in coding practices may have led to the appearance (but not the actuality) of increased average severity over time, but this is unlikely to be an important limitation. Coding techniques to enhance reimbursement are focused primarily on more complete documentation and on modifying DRGs to account for comorbidity, complications, and procedures, rather than on the AIS-based severity of specific ICD-9-CM injury codes, [Cole et al., 1998; Barnes et al., 2008]. A trauma center study found that the average AIS-based injury severity score was unchanged during a period of intense and successful focus on improved cost recovery [Helling et al., 1995]. The number of ICD-9-CM diagnosis fields contained in some hospital discharge data sets has risen over time, but we categorized severity using only the first-listed diagnosis for that reason. In a previous study based on the Washington State Trauma Registry, we observed a steeper increase in mean AIS-based injury severity scores for work-related injuries compared with other injuries, which would suggest at minimum that coding changes cannot be the sole explanation [Sears et al., 2011]. In addition, in that study, injury severity scores were based on ICD-9-CM codes generated for clinically descriptive purposes rather than on discharge/billing data and yet we observed an even stronger effect of severity restriction in that study than we did in the current study. The divergence in severity trends between comparable occupational and non-occupational injuries together with marked variation across states in the current study (particularly Florida) also weighs against generalized “coding creep” being an important driver of our findings.

Implications and Conclusions

In this study, we assessed the impact of severity restriction on injury rate trend estimates nationally and for four separate states (Arizona, Florida, New Jersey, and Washington). Restriction to *severe* injuries provided a markedly different picture of occupational injury trends than did including *all* injury-related hospitalizations. We conclude that downward trajectories in injury trends have been overstated, in part due to unavailable or inadequate severity measurement in combination with decreasing capture of less severe occupational injuries. Severity restriction has the potential to improve the accuracy of trend measurement by reducing temporal biases that may differentially affect minor injuries, such as increasingly restrictive hospital admission practices, constricting WC coverage and workforce changes, and decreasing identification or reporting of minor injuries as being work-related.

The NIOSH and CSTE Occupational Health Surveillance Work Group has developed 20 standard occupational health surveillance indicators that can be implemented using existing state data [Thomsen et al., 2007; Council of State and Territorial Epidemiologists (CSTE), 2013]. The second indicator is defined as the annual rate of hospitalizations of state residents 16 years or older with WC reported as the primary payer [Council of State and Territorial Epidemiologists (CSTE)]. However, hospitalizations are quite heterogeneous (e.g., injury, illness, surgery). We are working to develop a new occupational health surveillance indicator (Work-Related Severe Traumatic Injury Hospitalizations) that will include a standard definition of traumatic injury to reduce heterogeneity and will incorporate severity restriction. Severe traumatic injuries may prove to be a more consistent bellwether of work-related injury trends than all hospitalizations [Cryer and Langley, 2008].

This study also raises several important questions. (1) Do similar severe/minor trend differentials affect trends observed using WC and SOII data? Changing hospitalization practices could not be the driver, but issues more specific to WC might still have a differential effect on minor compared with severe injuries, such as constricting WC coverage and/or increasingly incomplete reporting of minor work-related injuries. (2) What methods could be used to implement a severity restriction if ICD-9-CM codes and AIS are unavailable? Time loss compensation has sometimes been used for severity restriction, but is more properly considered an outcome than a measure of injury severity, and is itself affected by WC structure, policy, and workplace environments. (3) How do counterposing pressures affect observed trends in different states? For example, while there may be an increasing tendency to cost-shift from WC to private insurance in some environments (e.g., if hospitals consider WC particularly burdensome relative to reimbursement rates, or if workers perceive substantial barriers to filing a WC claim), there may also be opposing pressures encouraging the filing of WC claims (e.g., rising rates of underinsurance).

Injury severity measures should be developed and prioritized for capture by existing and newly designed occupational injury surveillance mechanisms. Accurate characterization of injury trends is critical to monitoring our state and national progress with regard to occupational injury prevention. This study reinforces the need to expand hospital discharge databases and national surveys to include occupation and industry information as well as direct identification of work-related injuries, independent of payer. The ability to accurately identify underlying sources of increased injury rates and populations at increased risk is crucial in guiding preventive intervention plans.

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REFERENCES

Association for the Advancement of Automotive Medicine. 1990. The abbreviated injury scale, 1990 revision Des. Plaines, IL: AAAM.

Azaroff LS, Levenstein C, Wegman DH. 2002. Occupational injury and illness surveillance: Conceptual filters explain underreporting. Am J Public Health 92:1421–1429.

Azaroff LS, Lax MB, Levenstein C, Wegman DH. 2004. Wounding the messenger: The new economy makes occupational health indicators too good to be true. Int J Health Serv 34:271–303.

Baker SP, O'Neill B, Haddon W, Jr. Long WB. 1974. The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. J Trauma 14:187–196.

Barnes SL, Robinson BR, Richards JT, Zimmerman CE, Pritts TA, Tsuei BJ, Butler KL, Muskat PC, Davis K, Jr. Johannigman JA. 2008. The devil is in the details: Maximizing revenue for daily trauma care. Surgery 144:670–675; discussion 675–676.

Barrett M, Steiner C. 2010. Addendum to Healthcare Cost and Utilization Project (HCUP) E Code Evaluation Report. HCUP Methods Series Report # 2004–06: U.S. Agency for Healthcare Research and Quality.

Bowman SM, Aitken ME, Maham SA, Sharar SR. 2011. Trends in hospitalisations associated with paediatric burns. Inj Prev 17:166–170.

Bunn TL, Slavova S, Bathke A. 2007. Data linkage of inpatient hospitalization and workers' claims data sets to characterize occupational falls. J Ky Med Assoc 105:313–320.

Centers for Disease Control and Prevention. 2007. Nonfatal occupational injuries and illnesses–United States, 2004. MMWR Morb Mortal Wkly Rep 56:393–397.

Clark DE, Osler TM, Hahn DR. 2010. ICDPIC: Stata module to provide methods for translating International Classification of Diseases (Ninth Revision) diagnosis codes into standard injury categories and/or scores. http://ideas.repec.org/c/boc/bocode/s457028.html. Accessed March 2, 2012.

Colantonio A, Croxford R, Farooq S, Laporte A, Coyte PC. 2009. Trends in hospitalization associated with traumatic brain injury in a publicly insured population, 1992–2002. J Trauma 66:179–183.

Cole BJ, Flics S, Levine DB. 1998. Optimizing hospital reimbursement through physician awareness: A step toward better patient care. Orthopedics 21:79–83.

Council of State and Territorial Epidemiologists (CSTE). Occupational Health Indicators: A Guide for Tracking Occupational Health Conditions and Their Determinants. March 2013. www.cste.org/resource/resmgr/OccupationalHealth/OHIGuidanceMarch2013.pdf. Accessed February 11, 2014.

Council of State and Territorial Epidemiologists (CSTE). 2014. Occupational Health Indicators. http://www.cste.org/?OHIndicators. Accessed February 11, 2014.

Cryer C, Gulliver P, Langley JD, Davie G. 2010. Is length of stay in hospital a stable proxy for injury severity? Inj Prev 16:254–260.

Cryer PC, Jarvis SN, Edwards P, Langley JD. 1999. How can we reliably measure the occurrence of non-fatal injury? Int J Consum Prod Saf 6:183–191.

Cryer C, Langley JD, Stephenson SC, Jarvis SN, Edwards P. 2002. Measure for measure: The quest for valid indicators of non-fatal injury incidence. Public Health 116:257–262.

Cryer C, Langley J. 2008. Developing indicators of injury incidence that can be used to monitor global, regional and local trends. http://www.otago.ac.nz/ipru/ReportsPDFs/OR070.pdf. Accessed September 7, 2011.

Dembe AE, Mastroberti MA, Fox SE, Bigelow C, Banks SM. 2003. Inpatient hospital care for work-related injuries and illnesses. Am J Ind Med 44:331–342.

Dennison C, Pokras R. 2000. Design and operation of the National Hospital Discharge Survey: 1988 redesign. DHHS Publication No. (PHS) 2001-1315. Vital Health Stat 1.

Di Bartolomeo S, Tillati S, Valent F, Zanier L, Barbone F. 2010. ISS mapped from ICD-9-CM by a novel freeware versus traditional coding: A comparative study. Scand J Trauma Resusc Emerg Med 18:17.

Fay MP, Feuer EJ. 1997. Confidence intervals for directly standardized rates: A method based on the gamma distribution. Stat Med 16:791–801.

Friedman LS, Forst L. 2007a. Occupational injury surveillance of traumatic injuries in Illinois, using the Illinois trauma registry: 1995–2003. J Occup Environ Med 49:401–410.

Friedman LS, Forst L. 2007b. The impact of OSHA recordkeeping regulation changes on occupational injury and illness trends in the US: A time-series analysis. Occup Environ Med 64:454–460.

Groenewold MR, Baron SL. 2013. The proportion of work-related emergency department visits not expected to be paid by workers' compensation: Implications for occupational health surveillance, research, policy, and health equity. Health Serv Res 48:1939–1959.

Guo X, Burton JF, Jr. 2010. Workers' compensation: Recent developments in moral hazard and benefit payments. Ind Lab Relat Rev 63:340–355.

Harwood PJ, Giannoudis PV, Probst C, Van Griensven M, Krettek C, Pape HC. 2006. Which AIS based scoring system is the best predictor of outcome in orthopaedic blunt trauma patients? J Trauma 60:334–340.

HCUP State Inpatient Databases (SID). Healthcare Cost and Utilization Project (HCUP). 1998–2009. Rockville, MD: Agency for Healthcare Research and Quality (AHRQ). www.hcup-us.ahrq.gov/sidoverview.jsp. Accessed September 29, 2013.

Helling TS, Watkins M, Robb CV. 1995. Improvement in cost recovery at an urban level I trauma center. J Trauma 39:980–983.

Kilgo PD, Osler TM, Meredith W. 2003. The worst injury predicts mortality outcome the best: Rethinking the role of multiple injuries in trauma outcome scoring. J Trauma 55:599–606; discussion 606–607.

Klein RJ, Schoenborn CA. 2001. Age adjustment using the 2000 projected U. S. population. Healthy People Statistical Notes, no. 20. Hyattsville, Maryland: National Center for Health Statistics.

Langley J, Stephenson S, Cryer C. 2003. Measuring road traffic safety performance: Monitoring trends in nonfatal injury. Traffic Inj Prev 4:291–296.

Liu W, Cela J. 2008. Count Data Models in SAS, Paper 371-2008. SAS Global Forum 2008, Statistics and Data Analysis San Antonio, TX.

MacKenzie EJ, Steinwachs DM, Shankar B. 1989. Classifying trauma severity based on hospital discharge diagnoses. Validation of an ICD-9CM to AIS-85 conversion table. Med Care 27:412–422.

McGreevy K, Lefkowitz D, Valiante D, Lipsitz S. 2010. Utilizing hospital discharge data (HD) to compare fatal and non-fatal work-related injuries among Hispanic workers in New Jersey. Am J Ind Med 53:146–152.

Mendeloff J, Burns R. 2013. States with low non-fatal injury rates have high fatality rates and vice-versa. Am J Ind Med 56:509–519.

Meredith JW, Evans G, Kilgo PD, MacKenzie E, Osler T, McGwin G, Cohn S, Esposito T, Gennarelli T, Hawkins M, Lucas C, Mock C, Rotondo M, Rue L, Champion HR. 2002. A comparison of the abilities of nine scoring algorithms in predicting mortality. J Trauma 53:621–628; discussion 628–629.

Morse T, Dillon C, Kenta-Bibi E, Weber J, Diva U, Warren N, Grey M. 2005. Trends in work-related musculoskeletal disorder reports by year, type, and industrial sector: A capture-recapture analysis. Am J Ind Med 48:40–49.

Nahm NJ, Patterson BM, Vallier HA. 2012. The impact of injury severity and transfer status on reimbursement for care of femur fractures. J Trauma Acute Care Surg 73:957–965.

National Center for Health Statistics (NCHS). 2004. Expert Group on Injury Severity Measurement. Discussion document on injury severity measurement in administrative datasets. http://www.cdc.gov/nchs/data/injury/DicussionDocu.pdf. Accessed February 11, 2014.

National Trauma Data Bank. 2011. National Trauma Data Standard: Data Dictionary. 2012 Admissions. http://www.ntdsdictionary.org/dataElements/documents/NTDS2012_xsd.PDF. Accessed August 27, 2012.

Osler T, Baker SP, Long W. 1997. A modification of the injury severity score that both improves accuracy and simplifies scoring. J Trauma 43:922–925; discussion 925–926.

Ruestow PS, Friedman LS. 2013. Characterizing the relationship between in-hospital measures and workers' compensation outcomes among severely injured construction workers using a data linkage strategy. Am J Ind Med 56:1149–1156.

Sears JM, Bowman SM, Adams D, Silverstein BA. 2011. Occupational injury surveillance using the Washington State Trauma Registry. J Occup Environ Med 53:1243–1250.

Sears JM, Bowman SM, Silverstein BA, Adams D. 2012. Identification of work-related injuries in a state trauma registry. J Occup Environ Med 54:356–362.

Sears JM, Blanar L, Bowman SM, Adams D, Silverstein BA. 2013a. Predicting work-related disability and medical cost outcomes: Estimating injury severity scores from workers' compensation data. J Occup Rehabil 23:19–31.

Sears JM, Bowman SM, Adams D, Silverstein BA. 2013b. Who pays for work-related traumatic injuries? Payer distribution in Washington State by ethnicity, injury severity, and year (1998–2008). Am J Ind Med 56:742–754.

Sears JM, Blanar L, Bowman SM. 2014. Predicting work-related disability and medical cost outcomes: A comparison of injury severity scores and scoring methods. Injury 45:16–22.

Shishlov KS, Schoenfisch AL, Myers DJ, Lipscomb HJ. 2011. Non-fatal construction industry fall-related injuries treated in US emergency departments, 1998–2005. Am J Ind Med 54:128–135.

Sorock GS, Smith E, Hall N. 1993. An evaluation of New Jersey's hospital discharge database for surveillance of severe occupational injuries. Am J Ind Med 23:427–437.

Stephenson S, Langley J, Cryer C. 2005. Effects of service delivery versus changes in incidence on trends in injury: A demonstration using hospitalised traumatic brain injury. Accid Anal Prev 37:825–832.

STIPDA: Injury Surveillance Workgroup 5. 2007. Consensus recommendations for injury surveillance in state health departments. Atlanta, GA: State and Territorial Injury Prevention Directors Association.

Thomas KE, Johnson RL. 2012. State injury indicators report: Instructions for preparing 2010 data. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.

Thomsen C, McClain J, Rosenman K, Davis L. 2007. Indicators for occupational health surveillance. MMWR Recomm Rep 56:1–7.

Thurman D, Guerrero J. 1999. Trends in hospitalization associated with traumatic brain injury. JAMA 282:954–957.

U.S. Department of Labor Bureau of Labor Statistics. Fatal Occupational Injuries and Nonfatal Occupational Injuries and Illnesses, 2008. http://www.bls.gov/iif/oshwc/osh/os/oshs2008.pdf. Accessed February 11, 2014.

U.S. Department of Labor, Bureau of Labor Statistics. Injuries, Illnesses, and Fatalities. http://www.bls.gov/iif/data.htm. Accessed April 27, 2011.

U.S. House of Representatives Committee on Education and Labor. Majority Staff Report: Hidden Tragedy: Underreporting of Workplace Injuries and Illnesses. June 2008. http://www.cste.org/resource/resmgr/OccupationalHealth/HouseEdLaborCommReport061908.pdf. Accessed February 11, 2014.

Vuong QH. 1989. Likelihood ratio tests for model selection and non-nested hypotheses. Econometrica 57:307–333.

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