Final Progress Report

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Using Injury Severity to Improve Occupational Traumatic Injury Trend Estimates

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List of Terms and Abbreviations

AIC	Akaike Information Criterion
AIS	Abbreviated Injury Scale
AUC	Area under the receiver operating characteristic curve
CHARS	Comprehensive Hospital Abstract Reporting System
CI	Confidence interval
CPS	Current Population Survey
CSTE	Council of State and Territorial Epidemiologists
E-code	ICD-9-CM external cause of injury code
ED	Emergency department
EMS	Emergency Medical Services
HCUP	Healthcare Cost and Utilization Project
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
IRR	Incidence rate ratio
ISS	Injury Severity Score
L&I	Washington State Department of Labor & Industries
MaxAIS	Maximum Abbreviated Injury Scale score
N/A	Not available
NHDS	National Hospital Discharge Survey
NTDB	National Trauma Data Bank
NS	Not significant
OHI	Occupational Health Indicator
PV	Predictive value
SHR	Subhazard ratio
SID	State Inpatient Databases (HCUP)
STIPDA	State and Territorial Injury Prevention Directors Association
TL	Time loss compensation
TPD	Total permanent disability
WC	Workers' compensation
WTR	Washington State Trauma Registry

Abstract

Project title: Using Injury Severity to Improve Occupational Traumatic Injury Trend Estimates

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Acute work-related trauma is a leading cause of death and disability among U.S. workers, and is very costly for injured workers, employers, workers' compensation (WC) systems, and society as a whole. Accurate characterization of injury trends is critical to prevention planning and evaluation. This study investigated methods to improve injury trend estimation and produced information and tools directly useful for occupational injury surveillance and research. Findings fell into several substantive areas. First, the importance of severity restriction as a surveillance methodology was assessed using hospital discharge data from the National Hospital Discharge Survey and four states. 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. Severity restriction may minimize sources of temporal bias such as increasingly restrictive hospital admission practices, constricting WC coverage, and decreasing identification/reporting of minor work-related injuries. Second, a list of severe injury ICD-9-CM diagnosis codes was developed for surveillance purposes, and validated using Washington State Trauma Registry (WTR) data linked with WC data. Classification as a severe injury was a significant predictor of trauma registry inclusion, early hospitalization, compensated time loss, total permanent disability, and total medical costs. The severe injury list provides a simple and transparent alternative to injury severity estimation using proprietary software. Third, hospital discharge data from five states were used to calculate rates and trends for work-related injury hospitalizations, and substantial racial/ethnic disparities were documented. Fourth, there was substantial concordance between WTR and hospital discharge data for priority data fields, including payer, race/ethnicity, severity, and ICD-9-CM external cause of injury codes (E-codes). E-code based methods of identifying occupational injuries had high specificity (> 99%) but low sensitivity (< 14%). WC as payer was 76% sensitive and 98% specific. Many work-related injuries could not be identified using hospital discharge records. Fifth, occupational injury trends were substantially similar whether estimated using trauma registry or hospital discharge data. Rate estimates differed by data source, and were most similar when using a severity threshold. A mature state trauma registry with mandatory reporting can be used as an alternative to hospital discharge data for surveillance of severe work-related traumatic injuries, but incidence will be underestimated using either source. The primary translation achievement was a new Occupational Health Indicator (OHI) for state-based occupational injury surveillance. OHI #22 *"Work-Related Severe Traumatic Injury Hospitalizations"* has been adopted by the Council of State and Territorial Epidemiologists (CSTE). This study produced evidence that severity restriction is an important enhancement to injury surveillance methodology. More accurate trend estimates can be used by occupational health researchers, practitioners, and policy-makers to identify prevention opportunities and support investment in prevention efforts. This study demonstrated disparities in occupational injury rates in multiple states. This study also contributes to understanding the strengths and limitations of trauma registry and hospital discharge data. Finally, the severe injury list can be used to enhance occupational injury research, such as to control for confounding in program evaluation and outcome studies.

Section 1

Significant (Key) Findings

The overarching goal of this research was to investigate methods to produce more accurate estimates of trends in severe traumatic injuries and to provide occupational health researchers and policy-makers with information and tools directly useful for injury surveillance and research.

Importance of severity restriction as a surveillance methodology. Using hospital discharge data from the National Hospital Discharge Survey and four states (Arizona, Florida, New Jersey, and Washington), we assessed whether implementing a severity threshold would improve occupational injury surveillance. 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. Severity restriction may improve occupational injury trend estimates by reducing temporal biases such as increasingly restrictive hospital admission practices, constricting workers' compensation (WC) coverage, and decreasing identification/reporting of minor work-related injuries.

Severity measurement in evaluation and outcomes research. We constructed a severe injury indicator from the list of severe traumatic injury ICD-9-CM diagnosis codes developed during this grant. The severe injury indicator was a significant predictor of trauma registry inclusion, early hospitalization, compensated time loss, total permanent disability, and total medical costs. We concluded that severe traumatic injuries can be directly identified using ICD-9-CM diagnosis codes, providing a simple and transparent alternative to Abbreviated Injury Scale (AIS)-based injury severity estimation. The severe injury indicator was roughly comparable to AIS-based measures regarding information content. In addition, there was substantial agreement between the severe injury indicator constructed using Washington State Trauma Registry (WTR) clinical diagnoses and the severe injury indicator constructed using WC billing diagnoses (kappa=.75), suggesting that the diagnostic information contained in billing data is adequate for this purpose.

Disparities in occupational injury rates and trends. Hospital discharge data from five states (Arizona, California, Florida, New Jersey, New York) were used to calculate age-adjusted rates and trends for work-related injury hospitalizations. We found evidence of substantial multi-state disparities in occupational injury-related hospitalizations. Latinos were significantly more likely to have a work-related injury hospitalization. The disparity for Latinos was greatest for machinery-related hospitalizations. Latinos were also more likely to have a fall-related hospitalization. African-Americans were more likely to have an occupational assault-related hospitalization, but less likely to have a fall-related hospitalization. An additional hypothesis, that the degree of disparity in injury burden for Latinos has increased over time, was borne out only in one of the five states. In New York, we found a mean annual increase of 4.8% in the disparity for Latinos in traumatic injury hospitalizations, and a mean annual increase of 7.2% in disparity when restricted to severe traumatic injury hospitalizations. There was not significant divergence between the trend lines for Latinos and non-Latino whites in the other four states tested.

Concordance between trauma registry and hospital discharge data fields. We linked WTR and hospital discharge data to assess concordance for priority data fields, including payer, race/ethnicity, severity, death, and ICD-9-CM external cause of injury codes (E-codes). We found substantial agreement for data fields key to occupational injury surveillance and research, including WC as primary payer. However, many work-related injuries could not be identified using hospital discharge records. E-code based methods of identifying occupational injuries had high specificity (> 99%) but low sensitivity (< 14%). Payer was 76% sensitive and 98% specific.

Concordance between occupational injury rates and trends based on trauma registry and hospital discharge data. We documented substantial similarity between occupational injury trends estimated using either trauma registry or hospital discharge data from Washington State, despite the somewhat different populations and injury types represented. Rate estimates differed by data source, and were most similar when a severity threshold was applied. WTR maturity for the purpose of estimating injury rates and trends occurred about seven years after inception. We concluded that a mature state trauma registry with mandatory reporting requirements can be used as an alternative to population-based hospital discharge data for surveillance of severe work-related traumatic injuries, while acknowledging that the incidence of occupational injury hospitalizations will be underestimated using either data source.

Translation of Findings

Although this study did not result in a product directly transferable to workplaces, the primary translation goal was to develop a new Council of State and Territorial Epidemiologists (CSTE) Occupational Health Indicator (OHI) that could be used for state-based occupational injury surveillance. Our findings supported our primary hypothesis that when hospitalization data are used to calculate occupational injury trends in the absence of severity restriction, observed trends will be biased downward. We presented these findings at the 2013 CSTE Annual Conference. OHI #22 *"Work-Related Severe Traumatic Injury Hospitalizations"* received final approval from the CSTE Occupational Health Surveillance Subcommittee in December 2014, after pilot-testing by health department or WC agency staff in five states (California, Georgia, Missouri, New York, and Washington). Standardized methodological guidance for OHI #22 has now been included in CSTE's updated 2015 OHI Guide. This research project resulted in directly and immediately translated improvements to occupational injury surveillance.

Outcomes/ Impact

An important intermediate outcome of this study was the development and adoption of OHI #22 *"Work-Related Severe Traumatic Injury Hospitalizations"* for state-based surveillance. In order to facilitate implementation by state-based public health and occupational health programs, a simple and transparent case definition for surveillance of severe injuries was needed. Because of the limitations and complexities of existing software, our team developed a list of severe traumatic injury ICD-9-CM diagnosis codes, roughly corresponding to injuries with an AIS of 3 (serious) or above. This list was validated and included in the guidance for OHI #22.

There are also several potential outcomes of this study. This study produced evidence that supports the importance of using severity restriction as an injury surveillance methodology in order to produce more accurate trend estimates, which can then be used by occupational health researchers, practitioners, and policy-makers to identify prevention opportunities. Our findings that observed occupational injury trends are biased downward in the absence of severity restriction, potentially leading to unwarranted optimism, could materially affect future state and national investment in occupational injury prevention efforts. This study has contributed to an understanding of the strengths and limitations of trauma registry and hospital discharge data, each of which may be valuable in planning and evaluation of occupational injury prevention programs, improved case ascertainment for severe occupational injuries, and identification of high-risk populations and emerging injury patterns. This study also demonstrated disparities in occupational injury rates in multiple states. Finally, the severe injury list that was developed for OHI #22 can be used in a variety of ways to enhance occupational injury research, such as to control for confounding in program evaluation and outcome studies.

Section 2

Scientific Report

BACKGROUND

Acute work-related trauma is a leading cause of death and disability among U.S. workers. Every day, approximately 9,000 workers are treated in emergency departments (EDs), 200 are hospitalized, and 15 die due to traumatic injuries.[1] Severe traumatic injury can lead to long-term pain and disability and is very costly for workers' compensation (WC) systems and society as a whole.[2,3] 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. Numerous local, state, national, and private databases have been used for this purpose, but all have significant limitations and gaps.[4-9] At least 21 state trauma registries include an indicator of work-relatedness[6] making it feasible to identify work-related trauma. Trauma registries have been used in Alaska, Illinois, and now Washington for occupational injury surveillance.[4,10-14]

This study was motivated by our previous research exploring the Washington State Trauma Registry (WTR) as a resource for occupational injury surveillance, in which we observed an upward trend in traumatic injury reports (2003-2008).[14] In contrast, researchers working with the Illinois Trauma Registry found no significant change in occupational traumatic injury rates (1995-2003).[10] We excluded minor trauma (not done in the Illinois study) in order to limit expected inter- and intra-facility variation in reporting practices and found that doing so had a marked effect on observed trends. We found an upward trend in rates of moderate/major work-related trauma reports (age-adjusted mean annual increase: 5.3%; 95% CI: 3.3%, 7.4%), but a flat trend when all work-related trauma reports were included (0.9%; 95% CI: -0.7%, 2.4%).[14] The upward trend in rates of moderate/major traumatic injury reports was particularly steep for Latinos, and Latinos were the only demographic group that continued to exhibit a significant upward trend when all injuries were included.[14] This may be attributable to the confluence of more Latino representation and higher injury rates in the construction and agricultural sectors.[15-18] The all-year age-adjusted incidence rate ratio (IRR) for Latino workers compared with other workers was 2.60 in Washington,[14] compared with 2.44 in Illinois.[10] Although we observed increasing rates of the most severe injuries, occupational fatalities captured by the WTR have been decreasing, which comports with the decrease in Washington State occupational fatalities reported by the Fatality Assessment and Control Evaluation (FACE) program and the Census of Fatal Occupational Injuries (CFOI). Increasing rates of the most severe injuries would not necessarily translate into more fatalities if trauma care systems are meeting their goal of improving survival,[19] and in fact the WTR case survival rate has improved over time, most dramatically for those with major trauma.[20] Although work-related fatality rates among Latinos also declined from 1992 to 2006, Latinos consistently experienced higher rates than other workers.[21] The WTR represents an estimated 85% of qualifying trauma in Washington,[22] but is not population-based and has evolved and matured over time due to quality improvement efforts. The apparent decrease in lower severity injuries reported to the WTR may be a reflection of secular shifts in the types of facilities where minor trauma was treated or secular trends in trauma registry reporting as WTR inclusion criteria and training were refined to focus on the more severe injuries that the system was designed to address. Our exclusion of minor trauma appears to have unmasked upward trends specific to severe work-related trauma.

The upward trends we observed were robust but unexpected given previous research showing downward or flat trends in work-related injuries in recent years.[4] 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.[23] 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. 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,[24] specifically whether a particular injury is recognized and reported as work-related and whether a WC claim is filed and accepted. Studies based on data from the National Electronic Injury Surveillance System (NEISS-Work) have not found evidence of substantial downward trends in injury rates.[25,26] While several studies have reported declining trends in work-related hospitalizations, none controlled for severity.[27-29] It is possible that flat or upward trends in severe traumatic injuries have been obscured even in health care-based data sets due to inadequate severity measurement. To our knowledge, the potential importance of severity restriction to occupational injury surveillance has not been investigated. However, severity restriction has been discussed in the more general injury literature.[30] A report by the National Center for Health Statistics (NCHS) Expert Group on Injury Severity Measurement stated: "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."[31] 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.[32-34] Increasingly incomplete capture of minor injuries along with inadequate severity measurement may be a critically important issue affecting estimates of work-related injury trends in many surveillance efforts.[30] The 2nd of the Council of State and Territorial Epidemiologists (CSTE) set of standard occupational health surveillance indicators is defined as: "Annual number and rate of hospitalizations of state residents 16 years or older with workers' compensation reported as the primary payer."[27] Hospitalizations are very heterogeneous and severity is not discussed in the CSTE guide setting forth standardized definitions and methodology.[35] Severe traumatic injuries may prove to be a more consistent bellwether of work-related injury trends than all hospitalizations.[30]

SPECIFIC AIMS

Using the severity-related information available in population-based hospital discharge records for several states and the National Hospital Discharge Survey (NHDS), we sought to shed light on whether the rising trends in severe injuries reported to the WTR reflect genuine underlying trends in severe traumatic injury rates. Rising rates of severe traumatic injuries, particularly among Latinos, may reflect a trend toward more precarious and unregulated employment and a more vulnerable workforce, differentially impacting immigrant or otherwise marginalized populations in physically risky employment such as agriculture and construction.[18,29,36-38] Our primary hypothesis was that when hospitalization data are used to calculate occupational injury trends in the absence of a severity restriction, observed trends will be biased downward. Our secondary hypothesis was that a state trauma registry with mandatory reporting requirements can serve as a reasonably representative sample of all severe trauma cases and can justifiably be used for occupational injury surveillance. Trauma registries have several advantages over hospital discharge data, including details about the injury and initial treatment and often a specific work-related field that allows identification of work-related injuries independent of payer. The NIOSH and CSTE Occupational Health Surveillance Work Group has adopted 21 standard occupational health indicators (OHIs) that can be implemented for state surveillance using existing state data.[35,39] We developed a new state surveillance indicator (OHI #22 Work-Related Severe Traumatic Injury Hospitalizations), which was been adopted by CSTE based on work conducted during this grant. We also investigated methods to produce more accurate trend estimates in order to support improvements in surveillance and identification of prevention opportunities.

The aims (stated below) have not been modified from those in the original application, and have been fully realized. However, the new OHI was titled “Work-Related Severe Traumatic Injury Hospitalizations” instead of “Work-Related Traumatic Injury Hospitalizations.”

Specific Aim 1: Develop and submit a new occupational health surveillance indicator (Work-Related Traumatic Injury Hospitalizations) to the NIOSH-CSTE Occupational Health Surveillance Work Group. Using the NHDS and hospital discharge records from 4 states, assess: (1) whether identifying a stable subset of **severe** work-related nonfatal traumatic injuries by applying a severity restriction results in different trend estimates than those based on **all** hospitalized work-related nonfatal traumatic injuries, (2) whether trends diverge by race/ethnicity, and (3) whether particular injury types or causes may be driving trends.

Specific Aim 2: Assess whether a state trauma registry with mandatory reporting requirements can serve as a reasonable approximation to a population-based database for the purposes of work-related nonfatal severe traumatic injury surveillance. In particular, assess whether Washington State hospital discharge data validate the upward trends in work-related severe traumatic injuries reported to the WTR, as well as the increased rates and trends among Latinos. Use this information in conjunction with information on changes in WTR inclusion criteria and changes in reporting hospitals to assess the relative representativeness of the WTR over time.

Specific Aim 3: Link WTR and Washington State hospital discharge data to assess concordance for data fields particularly relevant to occupational health services research, including payer, race/ethnicity, severity, fatality data, and ICD-9-CM external cause of injury codes (E-codes). Use the linked data to evaluate E-code based methods of identifying work-related injuries in hospital discharge records.

The following sections (Methodology, Results and Discussion) are organized by specific aim. Every specific aim was fully addressed over the course of this project.

SPECIFIC AIM 1: ***Develop and submit a new occupational health surveillance indicator (Work-Related Traumatic Injury Hospitalizations) to the NIOSH-CSTE Occupational Health Surveillance Work Group. Using the NHDS and hospital discharge records from 4 states, assess: (1) whether identifying a stable subset of severe work-related nonfatal traumatic injuries by applying a severity restriction results in different trend estimates than those based on all hospitalized work-related nonfatal traumatic injuries, (2) whether trends diverge by race/ethnicity, and (3) whether particular injury types or causes may be driving trends.***

This aim was successfully completed (further details and a full presentation of results can be found in publications #1, #4, and #5 in the list of publications. The resulting new state-based OHI (Work-Related Severe Traumatic Injury Hospitalizations) was adopted by CSTE in December 2014, after pilot-testing by 5 states (CA, GA, MO, NY, WA). In this study, we assessed the impact of severity restriction on injury rate trend estimates nationally and for 9 states (AZ, CA, CO, FL, MI, NJ, NY, SC, WA). Restriction to severe injuries provided a markedly different picture of occupational injury trends than did including all injury-related hospitalizations. Due to variability in findings across the 4 initial states (AZ, FL, NJ, WA) regarding minor/severe injury trend differentials, we re-budgeted to purchase data from the Healthcare Cost & Utilization Project (HCUP) for 5 additional states (CA, CO, MI, NY, SC), in order to verify findings and enhance generalizability. These 5 additional states all followed the hypothesized pattern.

Our hypothesis that Latinos have shouldered a disproportionate burden of traumatic occupational injuries compared with the non-Latino white reference group, was supported by evidence from all five states in which it was tested (AZ, CA, FL, NJ, NY; selected due to race/ethnicity data completeness and sufficient diversity). Latinos were significantly more likely to have a work-related traumatic injury hospitalization, ranging from 1.42 times more likely in FL to 2.29 times more likely in NJ. Of the injury causes assessed, the disparity for Latinos was greatest for machinery-related occupational injury hospitalizations. Latinos were also consistently more likely to have a fall-related hospitalization. Although there was no evidence of an elevated risk of occupational injury hospitalization among African-Americans overall, African-Americans were significantly more likely to have an assault-related occupational injury hospitalization in all four states tested. An additional hypothesis, that the degree of disparity in injury burden for Latinos has increased over time, was borne out only in NY. In NY, we found a mean annual increase of 4.8% in the disparity for Latinos in traumatic injury hospitalizations, and a mean annual increase of 7.2% in disparity when restricted to severe traumatic injury hospitalizations. There was not significant divergence between the trend lines for Latinos and non-Latino whites in the other four states tested. Trends in disproportionate burden may truly vary by state, or trend estimates may be differentially affected by state-level differences in race/ethnicity reporting that may also change over time.

Although not affecting the scope of our specific aims, we did adjust our approach regarding identification of severe injuries in order to simplify implementation and translation activities, and to make the new OHI more readily accessible. Originally, we planned to revise the -icdpic-severity table, which would require access to and facility with Stata software by anyone wanting to use it. Instead, we worked with our expert AIS coder to construct a comprehensive list of ICD-9-CM diagnosis codes for severe injuries, which roughly corresponded to an AIS of 3 or above and/or a high probability of hospital admission. This eliminated the need for state health department and WC agency staff to use proprietary software programs.

Addressing Aim 1 involved conducting three essentially separate studies, thus the Methodology and Results and Discussion sections are presented separately for each sub-study.

Sub-study 1 (Aim 1): Trends by Injury Severity and Type

METHODOLOGY

Data sources and study population

Five distinct population-based data sets were initially used for this study, including the National Hospital Discharge Survey (NHDS) and four state hospital discharge databases (Arizona, Florida, New Jersey, and Washington). The NHDS is a freely available public use national probability sample of hospital discharges, available from the National Center for Health Statistics.[40] Hospital discharge data for Arizona, Florida, and New Jersey were obtained from HCUP, Agency for Healthcare Research and Quality. [41] Hospital discharge records for Washington State were obtained from the Comprehensive Hospital Abstract Reporting System (CHARS). The HCUP State Inpatient Databases (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 4 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%).[42]

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[43]). 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% to 8%) but roughly half of the non-occupational injury discharges (45% to 57%).

Traumatic injuries were defined using the ICD-9-CM diagnostic codes specified by the National Trauma Data Bank.[44] 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 severity measurement section below). By convention, the first-listed diagnosis in HCUP SID data is the principal diagnosis, which is defined in the Uniform Hospital Discharge Data Set (UHDDS) as “that condition established after study to be chiefly responsible for occasioning the admission of the patient to the hospital for care.”[45] HCUP considers inpatient principal diagnosis coding to be rigorous and well-scrutinized.[45] Inclusion was based only on the first-listed diagnosis, an approach that: (1) avoids temporal bias in trend estimation due to the increasing number of available diagnosis fields over time in some states, (2) avoids including injuries that occurred incidental or subsequent to hospital admission, and

(3) for the most part, captures the most severe injury.[46] This comports with injury surveillance recommendations promulgated by the Safe States Alliance (formerly STIPDA) and the Centers for Disease Control and Prevention (CDC).[46-48]

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."[35] 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%).[49] 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.[50] 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.[51] 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.[50]

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.[40] 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.[48] 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.[47]

The Abbreviated Injury Scale (AIS) was used to measure injury severity for this study.[52] 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.[30,31,34,53] AIS-based injury severity scores have been validated for prediction of mortality,[54-58] and recent studies have established their association with occupational injury outcomes such as work disability and medical costs.[59,60]

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.[61] The most serious injury, usually listed first if the primary reason for admission, has been found to predict mortality as well as all injuries.[58] 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.[30]

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.[35] 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.[62,63] 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+)[64] and gamma confidence intervals were calculated.[65] 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,[40] 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 AND DISCUSSION

Table 1 presents the results of the trend models for traumatic injuries having WC listed as the primary payer (for NHDS and the initial 4 states). 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 2). 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 claims cannot be distinguished from WC claims in Washington), the severe/minor interaction remained very similar to the estimate shown in Table 1 (trend ratio: 1.023; 95% CI: 1.002 - 1.045; p=0.03).

Table 1. Hospital discharge rates and trends for work-related traumatic injuries, by severity

Sample	Baseline (1998) injury rate per 100K employed		Mean annual % change			Interaction (severe trend/minor trend)		
	All	Severe	All	Severe	Minor	Trend ratio	95% CI	P-value
All injuries								
National (NHDS)	39.2	6.5	↓3.4*	↑1.5^{ns}	↓4.9*	1.067	1.023 - 1.112	0.001
Arizona	43.2	9.2	↓1.4^{ns}	↑0.4^{ns}	↓2.0^{ns}	1.024	0.981 - 1.069	NS
Age-adjusted	43.5	9.5	↓1.5^{ns}	0.0^{ns}	↓2.0^{ns}	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^{ns}	↓5.9*	1.057	1.033 - 1.081	<0.0005
Age-adjusted	55.1	8.0	↓5.1*	↓1.0^{ns}	↓6.1*	1.053	1.029 - 1.078	<0.0005
Washington	41.5	9.4	↓0.8^{ns}	↑1.5*	↓1.5*	1.031	1.011 - 1.050	0.002
Age-adjusted	41.6	9.6	↓0.7^{ns}	↑1.3^{ns}	↓1.4*	1.028	1.009 - 1.046	0.003
Falls								
Arizona	13.9	3.6	↑0.2^{ns}	↑1.3^{ns}	↓0.2^{ns}	1.015	0.968 - 1.065	NS
Florida	16.0	4.9	↓1.2*	↓1.8^{ns}	↓1.0^{ns}	0.992	0.971 - 1.014	NS
New Jersey	18.7	3.5	↓3.5*	↑0.1^{ns}	↓4.5*	1.048	1.026 - 1.071	<0.0005
Washington	16.4	3.9	↓0.5^{ns}	↑1.6^{ns}	↓1.2*	1.027	1.004 - 1.052	0.022
Motor vehicle traffic								
Arizona	4.5	1.4	↓1.3^{ns}	0.0^{ns}	↓1.9^{ns}	1.019	0.956 - 1.088	NS
Florida	4.9	1.7	↓1.7*	↓0.4^{ns}	↓2.6*	1.022	0.998 - 1.046	NS
New Jersey	5.8	1.5	↓3.0*	↓1.0^{ns}	↓3.8*	1.028	0.995 - 1.063	NS
Washington	3.5	1.2	↓3.6*	↓2.6^{ns}	↓4.1*	1.016	0.979 - 1.054	NS
Machinery								
Arizona	4.7	0.8	↓2.3^{ns}	↓0.3^{ns}	↓2.9^{ns}	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^{ns}	↓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

* Statistically significant trend (trend not flat, at P≤0.05)
^{ns}Not statistically significant
Note: Crude estimates are shown unless otherwise noted. NHDS, National Hospital Discharge Survey.

Figure 1 includes the trend lines for the initial five data sources 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.

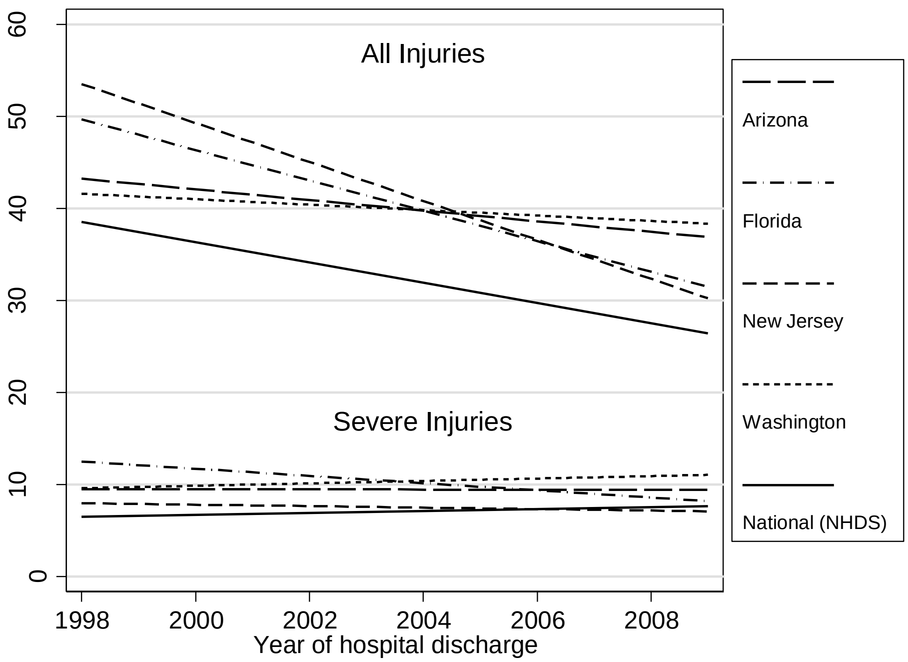

Figure 1. Impact of including only the severe subset of work-related traumatic injuries rather than all injuries when assessing temporal trends in occupational injury rates (five population-based data sources).

Table 2 presents results of the same analyses presented in Table 1, 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.

In every case, the trend line for severe work-related injuries either trended upward relative to minor injuries, or was not statistically different. As shown in Figure 1, even though the degree of bias varies by data source, the overall impact of severity restriction on observed trends 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.[30-34,66,67]

Table 2. Hospital discharge rates and trends for non-WC traumatic injuries, by severity

Sample	Baseline (1998) injury rate per 100K 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^{ns}	↑2.6*	↓0.9*	1.036	1.024 - 1.047	<0.0005
Arizona	379.2	115.7	0.0^{ns}	↑1.1^{ns}	↓0.4^{ns}	1.015	0.995 - 1.035	NS
Age-adjusted	378.0	115.7	0.0^{ns}	↑0.9^{ns}	↓0.4^{ns}	1.013	0.993 - 1.033	NS
Florida	313.0	103.0	↑0.7*	↑1.4*	↑0.3^{ns}	1.011	1.005 - 1.018	0.001
Age-adjusted	314.2	103.5	↑0.5*	↑1.1*	↑0.2^{ns}	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^{ns}	1.019	1.010 - 1.028	<0.0005
Age-adjusted	240.0	72.4	↑0.5^{ns}	↑1.7*	0.0^{ns}	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^{ns}	↑3.1*	↓0.9^{ns}	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^{ns}	↑0.5^{ns}	↓2.1^{ns}	1.027	0.984 - 1.071	NS
Florida	94.0	33.7	↑1.2*	↑2.6*	↑0.2^{ns}	1.024	1.011 - 1.037	<0.0005
New Jersey	85.9	22.9	↓2.5*	↓0.2^{ns}	↓3.5*	1.034	1.023 - 1.044	<0.0005
Washington	71.9	26.3	↓1.7*	↓0.9^{ns}	↓2.1*	1.013	1.000 - 1.026	0.042
Machinery								
Arizona	2.3	0.3	↓3.1*	↓6.6*	↓2.6^{ns}	0.960	0.894 - 1.030	NS
Florida	2.1	0.2	↓0.1^{ns}	↑2.3^{ns}	↓0.4^{ns}	1.028	0.984 - 1.074	NS
New Jersey	2.9	0.2	↓2.3*	↑0.3^{ns}	↓2.5*	1.029	0.977 - 1.084	NS
Washington	2.1	0.4	↓2.3*	↓9.9*	↓1.4^{ns}	0.914	0.862 - 0.969	0.002

* Statistically significant trend (trend not flat, at P≤0.05)

^{ns}Not statistically significant

Note: Crude estimates are shown unless otherwise noted. WC, workers' compensation; NHDS, National Hospital Discharge Survey.

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.[27-29] 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.[32-34]

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).[24,36] 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.[68] 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.[69] 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.[70] Hospitals have undertaken increasingly intensive efforts to identify potential payers and recoup the costs of care, particularly for the most expensive and severe injuries.[70-72] 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.[50] 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.

Sub-study 2 (Aim 1): Disparities by Race/Ethnicity

METHODOLOGY

Data sources and study population

Population-based community hospital discharge data for five states (AZ, CA, FL, NJ, NY) were obtained from HCUP.[73] These five states satisfied several selection criteria, including state reporting of WC as a distinct payer category (unlike the uniform SID payer field that does not maintain WC as a distinct payer category); state reporting of race/ethnicity data from 2003 through 2009, affordably-priced data available via HCUP/SID, and availability of adequate employed population denominator data (reported cell counts for each age and race/ethnicity stratum of interest). Occupational traumatic injury hospitalizations were included if hospital discharge occurred from 2003 through 2009, if WC was listed as the primary payer, and if the first-listed diagnosis was a traumatic injury. CSTE recommends the use of WC as primary payer to identify work-related hospitalizations.[35] Traumatic injuries were defined as described previously.

Measures

Race/ethnicity was based on the HCUP uniform data element, which contains mutually exclusive race and ethnicity categories in one data element (RACE). When constructing the uniform data element from separate race and ethnicity data fields in state source data, HCUP gave ethnicity precedence over race. Due to small numbers in some cells (for HCUP data and/or CPS data), most analyses in this study focused on three race/ethnicity categories; non-Latino white, Latino/Hispanic, and Black/African-American. Analyses in AZ were limited to the non-Latino white and Latino/Hispanic categories due to insufficient numbers of injury hospitalizations among African-Americans.

First-listed valid 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) machinery-related hospitalizations, and (3) motor vehicle traffic hospitalizations. E-codes were also used to classify manner/intent of injury; specifically a first-listed valid E-code of E960.X-E969, E979.X, or E999.1 was used to identify assault/homicide-related injuries (modeled on the CDC instructions for Homicide/Assault Indicator 2). Manner/intent categories overlap with cause categories. “Unspecified” and “undetermined” categories are based on specific E-codes and do not technically constitute missing data. However, the unspecified and undetermined categories are conceptually equivalent to missing data for some comparative purposes, and thus were treated as missing and excluded from some analyses.

Place of injury (E849.X) was constructed from all available E-codes (up to seven per record, which varied by state/year). Place of injury data were collapsed into four categories: (1) industrial/mine/quarry (E849.2, E849.3), (2) street/highway (E849.5), (3) other specified (E849.0, E849.1, E849.4, E849.6, E849.7, E849.8), and (4) unspecified (E849.9).

The Abbreviated Injury Scale (AIS) was used to measure injury severity for this study.[52] AIS was estimated from the first-listed ICD-9-CM diagnosis code using -icdpic-. We calculated annual rates separately for: (1) all traumatic injury-related hospitalizations, and (2) the subset of severe traumatic injury-related hospitalizations.

Data analysis

Crude and age-adjusted rates for the period from 2003 through 2009 were calculated for work-related injury hospitalizations overall and for each of the race/ethnicity categories. Age adjustment was performed using direct standardization based on the U.S. 2000 Standard Population (ages 16-64)[64] and gamma confidence intervals were calculated.[65] In the age-restricted samples used for this study, there were only slight and unremarkable differences between the crude and age-adjusted rates; therefore only age-adjusted rates were presented in the tables. Trends were calculated for the period from 2003 through 2009 using negative binomial regression models that included a continuous variable for discharge year and that adjusted for employed population denominators. These models were run once for all traumatic injuries and again for severe traumatic injuries only. For each state, we also assessed whether there was increasing disparity for Latinos or African-Americans compared with the non-Latino white reference group by adding interaction terms (year by race/ethnicity) to the models. Negative binomial regression models were also used to estimate all-year incidence rate ratios by race/ethnicity (using non-Latino white as the reference group), overall and stratified by injury cause. 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 AND DISCUSSION

The percentage of Latinos ranged from 10% in NJ to 42% in CA, and the percentage of African-Americans ranged from 2.2% in AZ to 25.7% in NJ. Annual occupational injury hospitalization rates are presented in Table 3. Rates for non-Latino whites and Black/African-Americans were roughly similar in general, while rates for Latinos were significantly higher in most years for most states.

Using the models designed to assess whether there was increasing disparity for Latinos or African-Americans compared with the non-Latino white reference group (by using interaction terms), we found no evidence of increasing divergence in linear trends for four of the five states. However, for NY, we did find evidence of increasing disparity for Latinos over time. The disparity between the trend line for Latinos relative to the trend line for non-Latino whites increased by an average of 4.8% per year (95% CI: 1.2%, 8.5%; $p=0.009$) for all traumatic injuries, and by an average of 7.2% per year (95% CI: 1.8%, 12.9%; $p=0.008$) for severe traumatic injuries.

Table 4 presents all-year incidence rate ratios for Latinos and for African-Americans, each compared with non-Latino whites, modeled separately for each state and for specified injury causes. These models accounted for employed population denominators and provided population-based estimates of the relative probability of occupational injury-related hospitalization for each group. Overall, Latinos were significantly more likely to have a work-related traumatic injury hospitalization compared with non-Latino whites, with estimates ranging from 1.42 times more likely in FL to 2.29 times more likely in NJ. In contrast, we did not find evidence for a disparity in overall occupational injury hospitalizations among African-Americans compared with non-Latino whites. Of the injury causes assessed, the disparity for Latinos was greatest for machinery-related occupational injury hospitalizations, with estimates ranging from 2.37 times more likely in FL to 5.70 times more likely in NJ. Across all five states, Latinos were also consistently more likely than non-Latino whites to have a fall-related hospitalization. In all four states tested, African-Americans were significantly more likely to have an assault-related occupational injury hospitalization compared with non-Latino whites, but significantly less likely to have a fall-related injury hospitalization.

Table 3. Annual rates of all occupational injury hospitalizations by race/ethnicity for five states (age-adjusted incidence rates per 100,000 employed workers)

Characteristic	2003 (CI)	2004 (CI)	2005 (CI)	2006 (CI)	2007 (CI)	2008 (CI)	2009 (CI)
Arizona							
Non-Latino White	20.3 (18.4-22.3)	24.1 (22.1-26.3)	27.3 (25.2-29.6)	29.3 (27.1-31.6)	25.9 (23.9-28.0)	23.8 (21.9-25.8)	17.1 (16.0-19.5)
Latino/Hispanic	45.9 (40.6-51.8)	57.4 (51.5-64.0)	73.9 (67.3-81.2)	66.4 (60.5-72.8)	58.7 (53.2-64.7)	46.7 (41.7-52.1)	31.4 (27.4-35.9)
California							
Non-Latino White	16.9 (16.1-17.6)	16.1 (15.4-16.9)	16.2 (15.5-17.0)	14.8 (14.1-15.5)	14.4 (13.7-15.1)	12.7 (12.1-13.4)	10.9 (10.3-11.5)
Latino/Hispanic	36.7 (34.7-38.8)	35.8 (33.9-37.8)	35.0 (33.3-36.9)	32.7 (31.0-34.4)	31.2 (29.5-32.8)	26.6 (25.2-28.1)	24.7 (23.2-26.2)
Black/African-American	12.9 (10.6-15.6)	17.7 (15.0-20.8)	15.8 (13.2-18.7)	15.8 (13.3-18.7)	13.2 (10.9-15.9)	12.2 (10.0-14.7)	12.7 (10.4-15.3)
Florida							
Non-Latino White	31.4 (30.0-32.9)	30.8 (29.5-32.3)	31.7 (30.3-33.1)	28.0 (26.8-29.3)	25.9 (24.7-27.1)	24.2 (23.1-25.5)	21.9 (20.7-23.1)
Latino/Hispanic	47.1 (43.5-51.0)	43.9 (40-5-47.5)	55.5 (51.8-59.5)	42.9 (39.9-46.2)	35.9 (33.1-38.8)	30.6 (28.0-33.4)	25.5 (23.0-28.1)
Black/African-American	32.6 (29.1-36.4)	35.3 (31.7-39.1)	36.2 (32.6-40.0)	33.1 (29.7-36.7)	29.6 (26.5-33.1)	25.5 (22.6-28.6)	19.5 (16.9-22.3)
New Jersey							
Non-Latino White	30.2 (28.3-32.3)	35.2 (33.1-37.3)	26.5 (24.7-28.4)	23.3 (21.6-25.1)	23.2 (21.5-24.9)	23.3 (21.6-25.1)	19.3 (17.8-21.0)
Latino/Hispanic	73.8 (66.0-82.4)	88.8 (80.7-97.6)	56.4 (50.4-63.0)	68.1 (61.3-75.5)	59.8 (53.6-66.7)	44.8 (39.7-50.4)	43.2 (38.2-48.7)
Black/African-American	29.8 (25.2-35.1)	44.4 (38.7-50.6)	26.8 (22.5-31.8)	28.8 (24.3-33.9)	27.9 (23.4-33.0)	26.0 (21.5-31.3)	22.8 (18.6-27.6)
New York							
Non-Latino White	28.4 (27.1-29.8)	29.5 (28.2-30.9)	28.6 (27.3-30.0)	26.9 (25.6-28.2)	25.0 (23.8-26.3)	24.9 (23.7-26.2)	22.2 (21.1-23.4)
Latino/Hispanic	34.9 (31.4-38.8)	40.2 (36.6-44.2)	41.9 (38.1-46.0)	40.3 (36.8-44.1)	48.6 (44.7-52.8)	37.9 (34.5-41.6)	35.6 (32.3-39.1)
Black/African-American	26.0 (23.2-29.1)	26.7 (23.9-29.7)	27.0 (24.2-30.0)	27.4 (24.6-30.5)	25.3 (22.6-28.2)	24.4 (21.8-27.2)	20.0 (17.5-22.7)

CI, confidence interval. Notes: Denominators based on Community Population Survey (CPS) estimates of employed population/subpopulations. Age-adjusted rates using year 2000 U.S. standard working population weights; 95% gamma confidence intervals.

Table 4. Incidence rate ratios by injury cause and race/ethnicity for five states, 2003-2009

Type of Injury	Arizona		California		Florida		New Jersey		New York	
	IRR	**95% CI**	**IRR**	**95% CI**	**IRR**	**95% CI**	**IRR**	**95% CI**	**IRR**	**95% CI**
All occupational injuries										
Non-Latino White	1.00	ref	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Latino/Hispanic	**2.28**	1.83-2.85	**2.08**	1.82-2.37	**1.42**	1.16-1.73	**2.29**	1.85-2.85	**1.48**	1.34-1.63
Black/African-American	n/a	n/a	0.97	0.84-1.12	1.05	0.86-1.29	1.11	0.89-1.39	0.94	0.85-1.04
Fall										
Non-Latino White	1.00	ref	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Latino/Hispanic	**2.44**	1.93-3.08	**1.86**	1.64-2.11	**1.39**	1.17-1.65	**1.66**	1.41-1.97	**1.27**	1.15-1.39
Black/African-American	n/a	n/a	**0.77**	0.65-0.91	**0.70**	0.58-0.83	**0.78**	0.65-0.95	**0.70**	0.63-0.77
Machinery										
Non-Latino White	1.00	ref	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Latino/Hispanic	**4.38**	3.38-5.68	**3.90**	3.11-4.90	**2.37**	1.91-2.94	**5.70**	4.79-6.77	**2.42**	2.12-2.76
Black/African-American	n/a	n/a	0.96	0.70-1.31	**1.92**	1.53-2.42	**1.64**	1.30-2.07	1.06	0.90-1.26
Motor vehicle traffic										
Non-Latino White	1.00	ref	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Latino/Hispanic	**3.30**	2.82-3.86	**1.45**	1.25-1.70	0.91	0.74-1.12	**1.28**	1.00-1.64	0.89	0.77-1.05
Black/African-American	n/a	n/a	**1.27**	1.03-1.57	**1.26**	1.02-1.55	**1.38**	1.07-1.77	1.09	0.94-1.27
Assault/homicide										
Non-Latino White	1.00	ref	1.00	ref	1.00	ref	1.00	ref	1.00	ref
Latino/Hispanic	0.97	0.62-1.51	**1.57**	1.30-1.89	1.16	0.82-1.66	**2.03**	1.33-3.09	**1.39**	1.04-1.86
Black/African-American	n/a	n/a	**2.10**	1.53-2.89	**1.89**	1.34-2.67	**3.07**	2.07-4.56	**2.76**	2.21-3.44

CI, confidence interval; ref, reference category; n/a, not available.

Our primary hypothesis, that Latinos have shouldered a disproportionate burden of traumatic occupational injuries compared with the non-Latino white reference group, was supported by evidence from all five included states. After adjusting for employed population denominators, Latinos were significantly more likely to have a work-related traumatic injury hospitalization, ranging from 1.42 times more likely in FL to 2.29 times more likely in NJ (Table 4). Of the injury causes assessed, the disparity for Latinos was greatest for machinery-related occupational injury hospitalizations. Latinos were also consistently more likely to have a fall-related hospitalization. Although there was no evidence of an elevated risk of occupational injury hospitalization among African-Americans overall, African-Americans were significantly more likely to have an assault-related occupational injury hospitalization in all four states tested.

Our secondary hypothesis, that the degree of disparity in injury burden for Latinos has increased over time, was borne out only in NY. In NY, we found a mean annual increase of 4.8% in the disparity for Latinos in traumatic injury hospitalizations, and a mean annual increase of 7.2% in disparity when restricted to severe traumatic injury hospitalizations. There was not significant divergence between the trend lines for Latinos and non-Latino whites in the other four states tested. In previous research using the WTR, we found that Latinos in Washington State bore an increasingly disproportionate burden of severe work-related traumatic injuries, on the order of a 5% annual increase in disparity.[74] Trends in disproportionate burden may truly vary by state, or trend estimates may be differentially affected by state-level differences in race/ethnicity reporting that may also change over time. In future studies, it will be important to investigate sources of the rising disparity in injury burden that we have observed for Latinos in NY and WA, as well as to investigate how widespread this rising disparity may be. Most states have not yet been assessed with respect to this issue.

Our findings do not account for differences in hazardous work exposures across states or across subpopulations within states. Higher rates of employment in more hazardous settings such as construction, agriculture, or late-night retail, for example, may in part account for the observed differences.[75-77] Hospital discharge data typically lack information on occupation, industry, and work status (e.g., whether self-employed, full-time, temporary, etc.). A number of occupational injury researchers have called for the addition of occupation, industry, and other work-related information to hospital databases used for surveillance activities.[4,14,78] Hospital discharge databases also do not contain data on nativity and immigration status, characteristics which are differentially prevalent across race/ethnicity strata. Immigrant workers are more likely to be employed in high-risk jobs, and may be at higher risk of injury even after accounting for occupation and industry.[77,79,80]

In the absence of occupation and industry, E-codes provide some minimal information about settings and mechanisms of injury. In general, E-codes are prevalent in hospital discharge records; for example, 91% of injury-related hospital discharge records provided to HCUP for 2010 did contain an injury E-code.[81] Many states encourage E-code reporting through the use of mandates, enforcement, or other strategies.[42] However, expectations for use of the place of injury E-codes (E849.X) vary across states. According to injury surveillance guidance that prioritizes mechanism over place of injury, place of injury is not considered a valid primary E-code; hence, place of injury cannot be captured when only one E-code field is available.[82] Although at least one valid primary E-code was present for the vast majority of records in every state, place of injury was much more often missing. Notably, although place of injury data was missing for 95% of NJ cases, the distribution of place of injury for NJ, was similar to that for the other states having markedly less missing data for place of injury. Improving the capture of place of injury information would provide more robust data regarding workplace characteristics leading to occupational injuries.

Previous studies in Illinois and Washington State have found that a higher proportion of Latinos had WC listed as an expected payer for work-related injuries, which could bias disparity estimates based on expected payer.[11,74] This observation may seem counter-intuitive, given higher barriers to claim-filing among more vulnerable populations that might be expected to more heavily impact Latino workers.[36,83] However, Latinos may more often have WC listed as an expected payer due to their disproportionate lack of other insurance coverage.[70,74]

All five of the included states are represented in the HCUP SID disparities analysis file, based on meeting criteria for acceptable reporting of race and ethnicity. However, California in particular had a high level of missing data for race/ethnicity (20.2% of WC cases, with a monotonic decrease from 22.8% in 2003 to 16.3% in 2009). Missing race/ethnicity data will affect rates via undercounting, and changes in the amount of missing race/ethnicity data over time could affect estimated trends. In addition to documented differences in data completeness, there may be differences in the way race and ethnicity information is collected and recorded, both across states and across time within states. Race/ethnicity information may rely on hospital staff observation rather than self-report, and there may be misclassification. There were discrepancies in the measurement of the numerator and denominator for the estimated rates. The HCUP databases used for the numerators each contain a single race/ethnicity data field with mutually exclusive categories. In contrast, the CPS data used for the denominators treat race and ethnicity as separate variables. Although this would affect the rate estimates, we believe the impact would be minor.

Sub-study 3 (Aim 1): Development and Validation of Severe Injury List

METHODOLOGY

Development of severe injury list

The list of severe traumatic injury diagnosis codes presented in Table 5 and used for this study was originally developed by our team for OHI #22. For purposes of the OHIs and for other WC-based research, it is desirable to have a simple and transparent method to identify severe injuries which doesn't require complex modeling and that can be easily implemented by state-based public health and occupational health programs. Mortality is often not fully captured in WC data, making the use of predictive injury severity models, such as the ICD-based Injury Severity Score (ICISS),[84] more challenging. Trauma registries typically contain AIS measures that were generated via expert assessment by trauma surgeons, review of medical records by trauma registrars, and/or estimated from International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis codes by trauma registry software.[22] In contrast, for injury research based on WC claims, there are typically large numbers of relatively minor injuries and small numbers of the most severe injuries.[59] WC billing data may contain ICD-9-CM diagnosis codes, but typically do not contain AIS scores. Two software packages that estimate injury severity scores directly from ICD-9-CM codes have been used for WC-based injury research:[59,60,85] (1) ICDMAP-90 software developed by and available from the Johns Hopkins Bloomberg School of Public Health,[86] and (2) Stata's user-written -icdpic- suite of programs, developed using the National Trauma Data Bank, which assigns approximate injury severity scores by classifying injuries into general severity and body region categories.[61] However, both methods have important limitations. ICDMAP-90 is not current to the most recent ICD-9-CM and AIS changes and cannot be run on newer computers. -icdpic- is freely available and easily run by Stata users; however, the crosswalk doesn't include the most recent ICD-9-CM codes, and is based on an outdated version of AIS.

The candidate list of ICD-9-CM diagnosis codes for severe traumatic injuries included only traumatic injury N-codes as defined by the National Trauma Data Bank (800-904.9, 910-929.9, 950-957.9, 959-959.9).[44] Isolated burns were excluded for reasons described earlier. As a starting point, we estimated AIS for each diagnosis code using both ICDMAP-90 and -icdpic-. AIS ranges from 1 (minor) to 6 (maximal). The primary intent was to identify traumatic injuries with an AIS of 3 or higher. These injuries are serious and usually result in hospitalization.[30] Our expert coder (M. Rotert) independently assigned AIS based on AIS 2008 (a more recent AIS version than that used by either software package). She initially reviewed all injury diagnosis codes for which ICDMAP-90 and -icdpic- assigned different AIS scores, as well as all those for which either ICDMAP-90 or -icdpic- assigned an AIS of 6. Our team then reviewed the entire list of diagnosis codes, discussed all discrepancies between the three sources of severity assignment, and assigned AIS (where possible) to diagnosis codes that were not scored by either ICDMAP-90 or -icdpic- (e.g., newly developed, rare, or combination codes). In general, we used the following rules for these assignments, leaning toward conservative severity assignments: (1) when the ICD-9-CM code mapped to more than one possible AIS, we assigned the lowest AIS, and (2) when the ICD-9-CM code included more than one definite injury (i.e., combination injuries), we assigned the lowest AIS for the most severe definite injury. Finally, we revised the resulting set of diagnosis codes to improve face validity based on our team's assessment of high probability of hospital admission, including, for example, all skull fractures and all crush injuries in the final severe injury list, even though AIS was estimated as lower than 3 for some individual injuries within those groups. Accurate severity assignment was balanced with simplicity; i.e., a few vague unscored ICD-9-CM codes were assigned the AIS of neighboring codes.

Table 5. ICD-9-CM codes for severe traumatic injuries ("x" indicates that all subcodes are also included)

ICD-9-CM code (range)	Code description
800.x, 801.x, 803.x	Fracture of skull
804.x	Multiple fractures involving skull or face with other bones
805.x, 806.x	Fracture of vertebral column with or without spinal cord injury
807.03-807.08, 807.13-807.18	Fracture of 3 or more ribs
807.2, 807.3	Sternum fracture
807.4	Flail chest
807.5, 807.6	Larynx or trachea fracture
808.x	Fracture of pelvis
812.1x, 812.3x, 812.5x	Fracture of humerus, open
813.1x, 813.3x, 813.5x, 813.9x	Fracture of radius or ulna, open
820.x, 821.x	Fracture of femur
823.1x, 823.3x	Fracture of upper end or shaft of tibia or fibula, open
824.5, 824.7	Bimalleolar or trimalleolar fracture of ankle, open
850.2, 850.3, 850.4	Concussion with moderate or prolonged loss of consciousness
851.x	Cerebral laceration/contusion
852.x, 853.x, 854.x	Subarachnoid, subdural, extradural, or intracranial hemorrhage/injury
860.x	Traumatic pneumothorax or hemothorax
861.x	Injury to heart or lung
862.8, 862.9	Injury to multiple and unspecified intrathoracic organs
863.x, 864.x, 865.x, 866.x	Injury to gastrointestinal tract, liver, spleen, or kidney
874.1x, 874.5	Open wound of larynx or trachea or pharynx, complicated
887.x, 896.x, 897.x	Traumatic amputation of arm, hand, foot, or leg
900.x, 901.x, 902.x	Injury to blood vessels of head, neck, thorax, abdomen, or pelvis
904.0, 904.1	Injury to common or superficial femoral artery
904.2, 904.3	Injury to femoral or saphenous vein
904.4x, 904.5x	Injury to popliteal or tibial blood vessels
925.x, 926.x, 927.x, 928.x, 929.x	Crushing injury
950.3	Injury to visual cortex
952.x	Spinal cord injury without evidence of spinal bone injury

Study population and data sources

Washington State has a single payer WC system (State Fund) that covers approximately 70% of workers who are covered by the Industrial Insurance Act.[87] Self-insured employers account for the remaining 30%; self-insured claims were excluded from this study because detailed medical billing and outcomes data were not available. All compensable WC claims were obtained from the Washington State Department of Labor and Industries for injuries occurring from 1998 through 2008, excluding injuries among those younger than 16 and those occurring outside Washington State. Injuries qualified for inclusion if there was at least one ICD-9-CM diagnostic code for a traumatic injury as specified by the inclusion criteria of the National Trauma Data Bank, with adjustments related to superficial injuries and burns (800-904.9, 910-929.9, 950-957.9, 959-959.9). Superficial injuries were included due to their prevalence and relevance to occupational injury research.[44] Isolated burns were excluded from this study; they were originally excluded from the severe traumatic injury list under investigation because AIS-based injury severity scores do not reliably classify burns due to the importance of inhalation injuries, which are not scored by AIS (or -icdpic-). Proximate fatalities (i.e., deaths before or during the initial injury hospitalization, or accepted fatal WC claims filed by survivors) were excluded because our population of interest was injured workers who might return to work; later deaths were treated as a competing risk/censoring mechanism.

WC claims were linked to WTR records and deduplicated using The Link King, a public domain software program developed in Washington State for deterministic and probabilistic linkage of administrative records.[88]. Further details about the data linkage procedure can be found in previous related publications.[14,50,59]

Severity measures

The severe injury list presented in Table 5 was converted into a binary severe injury indicator (set to 1 in the presence of any listed diagnosis; 0 otherwise), which was constructed using: (1) WC billing diagnoses (for all WC claims), and (2) WTR clinical diagnoses (for the linked subset). WC billing diagnoses included all available ICD-9-CM codes from facility and professional billing data for the first health care encounter occurring within 30 days after the injury date. WTR clinical diagnoses included all available ICD-9-CM codes from the first reported hospitalization. We labeled the resulting two groups as severe and minor/indeterminate, in order to emphasize that this indicator doesn't necessarily identify every severe injury. The minor/indeterminate group contains both relatively minor injuries and those that couldn't be accurately classified with respect to severity due to nonspecific ICD-9-CM codes.

We used -icdpic- to estimate several AIS-based injury severity measures from WC billing data, for comparison with the severe injury indicator. We have previously found substantial agreement between injury severity scores estimated by -icdpic- and ICDMAP-90.[85] We focused on two recognized injury severity scores: (1) Injury Severity Score (ISS), which has been well-validated for the prediction of mortality[54] and remains the most common measure of injury severity used by trauma systems and in trauma research, and (2) the overall maximum AIS (maxAIS), which performs as well as the ISS in some circumstances.[57,58,85] The ISS is the sum of squares of the highest AIS scores from up to three different body regions. The ISS has a range of 1 to 75, with 75 assigned whenever maxAIS is 6. ISS is technically non-continuous; thus we constructed a five-category ISS (1-3, 4-8, 9-15, 16-24, 25-75) following the methods recommended by Copes et al.,[89] which we extended to reflect the nuances of WC data (i.e., large numbers of minor injuries and small numbers of the most severe injuries).[59] Because the severe injury indicator under investigation is binary, and because very few injuries in the WC data have an estimated AIS of 3 or more (<5%), the ISS and maxAIS were converted to binary severity measures for some analyses (cut at 9+ and 3+, respectively).

Outcome samples and measures

Outcomes data were extracted from WC records in December of 2010, allowing for 2 to 13 years of follow-up, depending on when the injury occurred. The number of compensated lost work days was used as a proxy for length of work disability. The end of time loss compensation without total permanent disability (TPD) determination or death usually, but not always, means that the worker is able to or has returned to work. TPD (also known as permanent total disability, or PTD, in many jurisdictions) is determined when medical and vocational evaluations indicate that the injury prevents the worker from ever becoming gainfully employed, and confers eligibility for a pension. Time loss compensation is not measured comparably for two types of WC claims, Kept on Salary (KOS) and Loss of Earning Power (LEP), which were therefore excluded from the work disability analyses (but included for medical cost analyses). The sample available for work disability analyses consisted of 191,820 injury events.

Total medical costs were based on paid-to-date facility, professional, and pharmacy costs for closed claims. Open claims were excluded from cost analyses. Total medical costs were adjusted to December 2008 based on month and year of injury, using the medical care component of the Consumer Price Index. The sample available for medical cost analyses consisted of 200,800 injury events.

In addition to work disability and cost outcomes, we also assessed the severe injury indicator's association with mortality and with two measures of medical intensity, namely inclusion in the WTR and early hospitalization. Early hospitalization has been found to be a strong correlate of longer term disability.[90] Early hospitalization was defined as the presence of any inpatient hospital bill for a date of service within 30 days after the injury. Deaths are recorded in the WC claims data when known; however, deaths are likely to be underreported and are not necessarily related to the work injury.

Data analysis

Analyses were performed using Stata/MP 13.1 for Windows (StataCorp LP, College Station, TX). There were 4,302 eligible WC claims that linked to WTR records; we used this subset to assess concordance between WC-based and WTR-based versions of the severe injury indicator by calculating Cohen's kappa. We also used Cohen's kappa to assess concordance between three binary WC-based severity measures: (1) the severe injury indicator, (2) binary maxAIS (cut at 3+), and (3) binary ISS (cut at 9+). Landis and Koch's guidelines were used to assess the results.[91]

Claims are closed when an injured worker is deemed able to work, when TPD is determined, or upon the person's death. Information about length of time loss compensation and TPD determination was censored for open claims. We used a competing risks survival analysis approach for the work disability analyses, with days of time loss compensation as the time scale.[92] We evaluated two outcome events of primary interest: (1) the end of time loss compensation without TPD (as a proxy for ability to return to work), and (2) TPD. The alternate outcome and death were assigned as the competing risks. The Stata command -stcrreg-[93] (based on the Fine and Gray semiparametric method [94]) was used to produce subhazard ratios (SHR) for each outcome event of interest. Adjusted total medical costs were modeled using ordinary least squares regression (OLS) with robust variance estimates.[95]

All models included gender and a set of age category indicators (16-24 as the referent category, 25-34, 35-44, 45-54, 55-64, 65+). This provided a naïve model to use as a comparator for the models that also included severity measures. No cases had missing age data. One case with missing gender was dropped from the regression models.

The Akaike Information Criterion (AIC) allows for direct comparison of non-nested models when the outcome variable and sample size are the same.[96] AIC rewards goodness of fit, penalizes increasing degrees of freedom, and estimates relative information content. Within each set of outcome models, we calculated Δ AIC for each model by subtracting the AIC for the best model. The larger the Δ AIC, the more information was lost from that model relative to the best model (for which Δ AIC=0). Differences in amount of variance explained (R^2) were also compared for the cost models (R^2 cannot be calculated for the competing risk models). Many of the analyses and tables in this study were intentionally designed to be similar to an earlier study that demonstrated the value of estimating AIS-based severity measures from WC data, in order to facilitate direct comparison of findings.[59]

RESULTS AND DISCUSSION

The work disability sample contained 191,820 claims, of which 4.8% were classified as severe. The cost sample contained 200,800 claims, of which 4.7% were classified as severe. There was moderate to substantial agreement between the WC-based severe injury indicator and each of the two binary AIS-based severity measures that we estimated from WC billing data: the maxAIS indicator (kappa=0.60; agreement=97.0%) and the ISS indicator (kappa=0.62; agreement=97.0%). For the subset of 4,302 WC claims linked to WTR records, there was substantial agreement between the severe injury indicator constructed using WTR diagnoses, which classified 60.8% as severe, and the severe injury indicator constructed using WC medical billing diagnoses, which classified 64.4% as severe (kappa=0.75; agreement=88.2%).

Table 6 presents observed outcomes for the work disability sample by injury severity group. Compared with minor/indeterminate injuries, severe injuries were significantly more likely to be reported to the WTR, involve an early hospitalization, result in TPD or death, and have an unresolved claim at the end of the observation period. [Note: Deaths captured in WC claims data are not necessarily related to the work injury. Although there are many deaths in the minor/indeterminate injury group, the mortality rate for minor/indeterminate injuries is roughly 82 deaths per 100,000 claims per year of observation, compared with 148 for severe injuries. Mortality rates for both groups are much lower than the roughly 277 all-cause annual deaths per 100,000 Washington State civilian residents ages 15-64, in part due to incomplete mortality capture by WC data, and likely in part due to the healthy worker effect.]

As shown in Table 7, median time loss duration for severe injuries was more than twice that for minor/indeterminate injuries. As shown in Table 8, mean and median adjusted total medical costs for severe injuries were roughly three times higher than for minor/indeterminate injuries.

Table 9 presents the results of the competing risk survival analysis models used to assess the effect of injury severity on work disability. Table 9 also presents the results of the OLS model used to assess the effect of injury severity on adjusted total medical costs. Workers with severe injuries were about two-thirds as likely to have their time loss compensation end (without TPD determination or death) at any given time compared with those with minor/indeterminate injuries. Severe injuries were more than two and one-half times as likely to result in a TPD determination compared with minor/indeterminate injuries. Workers with severe injuries had $17,991 higher adjusted total medical costs on average than those with minor/indeterminate injuries. These were overly parsimonious models and these estimates are provided just as examples; observed effect sizes will vary depending on details of the sample, setting, covariates, outcome definitions, etc. However, these results demonstrate that the severe injury indicator is a significant predictor of time loss duration, TPD, and total medical costs.

Table 10 presents information content of the outcome regression models for all severity measures assessed. All models that included a severity measure were highly significant ($p \leq 0.0001$). Δ AIC can be compared only within each outcome (vertically). The best model for each model set has Δ AIC=0. The distance from 0 indicates the amount of information lost relative to the best model within each outcome model set, and absolute differences between other models within an outcome model set are also informative. All models that included any severity measure were more informative than those including just age and gender. For all outcomes, inclusion of the five-category ISS resulted in the most informative model. Among the three binary severity measures, results differed by outcome. The binary ISS indicator contributed the most information for all three outcomes, but was least dominant and comparable to the severe injury indicator for the TPD outcome.

Table 6. Clinical and claim outcomes by injury severity group (work disability sample, N=191,820)

Outcome	All injuries		Severe injuries		Minor/indeterminate		P-value
	n	%	n	%	n	%	
Reported to WTR	3,959	2.1	2,549	27.9	1,410	0.8	<0.0005
Early hospitalization	45,460	23.7	5,118	56.0	40,342	22.1	<0.0005
TPD/pension	3,602	1.9	447	4.9	3,155	1.7	<0.0005
Died	1,006	0.5	81	0.9	925	0.5	<0.0005
Claim still open/censored	7,710	4.0	677	7.4	7,033	3.9	<0.0005

TPD, total permanent disability; WTR, Washington State Trauma Registry.

Table 7. Compensated time loss duration by injury severity group (work disability sample)

Severity group	n	%	Median days	95% CI
Severe injuries	9,133	4.8	68	65-72
Minor/indeterminate	182,687	95.2	26	26-27
All injuries	191,820	100.0	27	27-28

Table 8. Adjusted total medical costs (dollars) by injury severity group (cost sample)

Severity group	n	%	Total for life of claim (closed claims only)				
			Mean	SE	25th percentile	Median	75th percentile
Severe injuries	9,501	4.7	27,114	925	2,110	8,759	26,874
Minor/indeterminate	191,299	95.3	9,293	42	894	2,790	9,855
All injuries	200,800	100.0	10,136	60	925	2,929	10,389

Table 9. Work disability and medical cost outcomes regressed on injury severity group

Severity group[a]	TL ended without TPD (N=191,819)		TPD (N=191,819)		Total medical costs (dollars) (N=200,799)	
	SHR	95% CI	SHR	95% CI	β	95% CI
Severe injuries	0.668	0.654 - 0.682	2.62	2.37 - 2.89	17,991	16,181 - 19,801
Minor/indeterminate	1	reference	1	reference	0	reference

SHR, subhazard ratio; TL, time loss; TPD, total permanent disability.
[a] Models included age, gender, and the severe injury indicator; 1 case was excluded from each sample due to missing gender.

Table 10. Comparison of amount of information contributed to regression models by severity measures

Model[a]	TL ended without TPD (N=191,819)	TPD (N=191,819)	Total medical costs (N=200,799)	
	Δ AIC[b]	Δ AIC[b]	R^2	Δ AIC[b]
Reference (age/gender only)	2803	369	0.006	11440
Severe injury indicator (severe, minor/indeterminate)	1418	89	0.026	7343
Binary maxAIS indicator (1-2, 3-6)	1288	108	0.033	6008
Binary ISS indicator (1-8, 9-75)	845	82	0.035	5570
Five-category ISS (1-3, 4-8, 9-15, 16-24, 25-75)	0	0	0.061	0

AIC, Akaike Information Criterion; AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; maxAIS, maximum AIS; SHR, subhazard ratio; TL, time loss; TPD, total permanent disability.
[a] All models included age and gender; 1 case was excluded from each sample due to missing gender.
[b] Δ AIC can be compared only within each outcome (vertically). The best model for each model set has Δ AIC=0; higher numbers for Δ AIC indicate more loss of information relative to the best model.

Compared with minor/indeterminate injuries, injuries classified as severe were significantly more likely to be reported to the WTR, involve an early hospitalization, result in TPD or death, have higher total medical costs, and have an unresolved claim at the end of the observation period. Although the five-category ISS clearly resulted in the most informative models, the binary severe injury indicator was roughly comparable to the binary AIS-based measures. Fewer than 5% of injuries in this WC-based sample were classified as severe by any of the methods used, and there may be little advantage to having the additional severity categories offered by AIS at the upper end of the scale, particularly in smaller samples where injuries with an AIS of 3 or above would likely be collapsed into a single category for analysis. In addition, there was substantial agreement between the severe injury indicator constructed using WTR clinical diagnoses and the severe injury indicator constructed using WC billing diagnoses (kappa=.75), suggesting that the diagnostic information contained in billing data is adequate for this purpose.

When AIS is available or AIS estimation is feasible, the severe injury indicator described herein offers no particular advantage. In fact, when the sample is large and contains substantial variability in injury severity, it will be unquestionably more informative to use a multiple-category AIS-based score such as ISS. However, existing methods to estimate AIS-based injury severity from ICD-9-CM diagnosis codes have important limitations, e.g., requiring use of out-of-date platforms or proprietary software, not being current to the most recent coding revisions, or not allowing for transparent updating. It is also important to note that there is no single straightforward and direct crosswalk between AIS and ICD-9-CM. These coding systems were developed by different organizations for different purposes. Some ICD-9-CM codes can be mapped to more than one AIS, or are so vague that they cannot be mapped with confidence to any AIS.

In settings where use of a simple diagnosis list is more feasible than use of ICDMAP-90 and/or -icdpic-, this severe injury indicator may facilitate control for injury severity that might not otherwise occur. Where the intent is not to predict individual outcomes but rather to employ a basic level of control for confounding by severity or identify a group of more severe cases, this list of severe traumatic injuries may be adequate and useful. Another potential strength is that the same list of severe traumatic injury diagnoses is already being used for state-based surveillance of occupational injuries, which may facilitate translation for additional uses. The list of severe traumatic injury diagnoses is transparent and easily modified by the user to suit their purposes. The list was developed in part using AIS 2008, which is a more current version than that used by either ICDMAP-90 or -icdpic-. The severe injury indicator can also be used if only a single diagnosis field is available for each injury, unlike ISS, which requires a bare minimum of three available diagnosis fields and preferably more.

Alternatively, an indicator of early hospitalization is also relatively easy to construct, captures substantially more cases than the severe injury indicator, and has been found to predict work disability and cost outcomes.[59,90] However, early hospitalization is also a measure of clinical intervention, and could be considered an outcome for some studies (for example, whether surgery is performed two weeks after a back injury). Inpatient hospitalization and length of stay are subject to a number of influences other than severity or medical need, such as changes in standards of care and service delivery over time.[53] In contrast, this severe injury indicator classifies initial injury severity. Injury severity adjustment may be useful as an adjunct (rather than alternative) to other forms of risk adjustment based on related but separate constructs (such as the Charlson comorbidity index,[97] which can also be estimated from ICD-9-CM codes using -icdpic- or Stata's -charlson- program).

Medical aid-only claims were not available for this study (claims that did not involve any missed work days after the initial three-day post-injury waiting period). Self-insured claims were also excluded due to unavailable/inadequate ICD-9-CM codes and outcomes data, and they may have a different injury severity mix and different outcomes than the State Fund population. It should be noted that although it is a commonly-used proxy, the end of time loss compensation has been found to underestimate the actual amount of time lost from work.[98]

The severe injury indicator is applicable only for the subset of traumatic injuries. For example, nonspecific back pain is an important condition for WC research but unless linked to a specific traumatic injury, cannot be classified by this indicator. This may the most important limitation, since nonspecific back pain is a large contributor to work-related time loss and costs. However, this doesn't detract from the potential value of this indicator for studies that focus on specific traumatic back injuries (e.g., sprains, strains) or on other traumatic occupational injuries such as amputations. Burns were excluded from this study (which accounted for fewer than 1.5% of otherwise eligible injuries) because burn diagnoses were not included in the severe injury diagnosis list for the reasons already described. Although beyond the scope of this study, further research to assess whether particular burn diagnoses could be added to the severe injury diagnosis list would be useful, which might obviate the need to exclude isolated burns during construction of the severe injury indicator.

SPECIFIC AIM 2: ***Assess whether a state trauma registry with mandatory reporting requirements can serve as a reasonable approximation to a population-based database for the purposes of work-related nonfatal severe traumatic injury surveillance. In particular, assess whether Washington State hospital discharge data validate the upward trends in work-related severe traumatic injuries reported to the WTR, as well as the increased rates and trends among Latinos. Use this information in conjunction with information on changes in WTR inclusion criteria and changes in reporting hospitals to assess the relative representativeness of the WTR over time.***

This aim was successfully completed (further details and a full presentation of results can be found in publication #3 in the list of publications). We found substantial similarity between occupational injury trends estimated using either trauma registry or hospital discharge data, despite the somewhat different populations and injury types represented. Rate estimates differed by data source, and were most similar when a severity threshold was applied. In the case of Washington State, trauma registry maturity for the purpose of estimating injury rates and trends occurred about seven years after inception. We concluded that a mature state trauma registry with mandatory reporting requirements can be used as an alternative to population-based hospital discharge data for surveillance of severe work-related traumatic injuries, while acknowledging that the incidence of occupational injury hospitalizations will be underestimated using either data source. Washington State hospital discharge data was too incomplete with regard to race/ethnicity information to address trends among Latinos as planned, however, this issue was addressed in a more comprehensive way using data from multiple other states (see Aim 1).

METHODOLOGY

Data sources and study population

Data for traumatic injury-related inpatient hospital discharges were obtained from two databases maintained by the Washington State Department of Health: (1) the Comprehensive Hospital Abstract Reporting System (CHARS), and (2) the Washington State Trauma Registry (WTR). CHARS contains inpatient hospital discharge information derived from billing records for all Washington State community hospitals. The WTR contains mandatory reporting data for traumatic injuries meeting specific inclusion criteria from all state-designated acute trauma facilities (Levels I through V).

For this aim, we included traumatic injury hospital discharges occurring from 1998 through 2009, for Washington State residents aged 16 through 64. Traumatic injuries were defined using the ICD-9-CM diagnostic codes specified by the NTDB.[44] 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 an ICD-9-CM 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 (see Injury Severity section below). For CHARS, inclusion was based on a qualifying injury being the first-listed diagnosis, in order to exclude incidental/superficial injuries. This comports with injury surveillance recommendations promulgated by the Safe States Alliance (formerly STIPDA) and the Centers for Disease Control and Prevention (CDC).[47,48] For the WTR, traumatic injuries that did not result in inpatient admission were excluded.

For CHARS, work-related injuries were identified as those having WC listed as primary expected payer, following the practice recommended by the Council of State and Territorial Epidemiologists (CSTE) for constructing state-based Occupational Health Indicators.[35] The L&I payer category captures both State Fund and self-insured WC coverage. However, the covered population does not include federal employees or exempt/excluded employment (e.g., sole proprietors, domestic workers, etc.).

In contrast to the nearly complete payer data contained in CHARS, the WTR has relatively high and inconsistent levels of missing payer data (see Results section for data). For the WTR, reliance on payer thus presents a threat to estimating accurate trends in work-related injuries. However, unlike hospital discharge databases, the WTR contains a data field that can be used to directly identify work-related injuries independently of payer. This work-related field has been shown to be highly sensitive (87%) and specific (97%) in identifying work-related injuries.[50] Therefore, for the WTR, work-related injuries were identified using the work-related data field.

In addition to differences in the way we identified work-related injuries in CHARS and the WTR, the two databases do not represent identical populations. In a nationwide survey conducted in 2004 by Mann, et al., the WTR trauma manager estimated that the WTR captured about 85% of statewide trauma victims with injuries satisfying registry inclusion criteria.[22] However, the WTR does not capture data for the many occupational injuries that do not involve transport to or treatment at a trauma hospital or that do not otherwise meet inclusion criteria.[20]

The specific WTR inclusion criteria have undergone some refinements over time. For most of the included years, reports were mandatory for adult patients who (1) were discharged with ICD-9-CM diagnosis codes of 800-904 or 910-959 (injuries), 994.1 (drowning), 994.7 (asphyxiation), or 994.8 (electrocution), and (2) met at least one of the following criteria: trauma resuscitation team activation, dead on arrival, death during the emergency department (ED) visit or associated hospital stay, interfacility transfer by Emergency Medical Services (EMS) or ambulance, or inpatient admission of at least 48 hours. (Note: Only inpatient WTR cases were included to enhance comparability, but the full WTR database also includes patients treated only in the ED that were not admitted but that otherwise met reporting criteria, e.g., patients transported in by EMS.) During the timeframe of this study, there were two changes to the WTR inclusion criteria that may have marginally affected the number and severity of traumatic injury reports. In brief, as of May 6, 2000, drowning, asphyxiation, and electrocution were added as qualifying diagnoses. As of December 17, 2009, being flown in from the scene was added to the reporting criteria. Overall, these changes in the WTR inclusion criteria were a reflection of the maturation of Washington's EMS and trauma system.

Injury severity

For some analyses, we restricted the samples to severe traumatic injuries, to make the CHARS and WTR injury samples more comparable. The Abbreviated Injury Scale (AIS) was used to classify injury severity.[52] We used a recognized ordinal measure of injury severity, the overall maximum AIS score (MaxAIS).[57,58] MaxAIS ranges from 1 (minor) to 6 (maximal), and is a measure of the most severe injury. AIS scores are present as data fields in the WTR, having been calculated either by the trauma registrar or by the trauma registry software. For CHARS, these scores were estimated from all 25 available ICD-9-CM diagnosis codes using -icdpic-, a Stata user-written program.[61] The -icdpic- program contains a crosswalk from ICD-9-CM diagnosis codes to AIS severity, developed using NTDB data.[61] Burns were excluded 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. We defined severe injury as a

MaxAIS of 3 (serious) or above; these injuries are more likely to be captured in both the trauma registry and CHARS. These severe injuries also carry a high probability of hospital admission; observed trends in severe injuries are less likely to be affected by temporal trends in hospital admission practices and thus more reflective of trends in underlying injury incidence.[30,99]

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.[35] Crude and age-adjusted rates for the period from 1998 through 2009 were calculated for work-related injury hospitalizations. Age adjustment was performed using direct standardization based on the U.S. 2000 Standard Population (ages 16+) [64] and gamma confidence intervals were calculated.[65] Negative binomial regression models that included a continuous variable for discharge year and an offset for denominator at risk were used to model linear trends. Linear trends were estimated for two different time periods using CHARS and WTR data: (1) 1998 through 2009, representing all years available for this study); and (2) 2002 through 2009, representing all years after apparent WTR maturation). Negative binomial regression was used in preference to Poisson models because the Vuong test often indicated overdispersion.[62,63] Models were run with and without severity restriction. All statistical tests were two-tailed, with statistical significance defined as $p \leq 0.05$. Analyses were performed using Stata/MP 13.0 for Windows (StataCorp LP, College Station, TX).

RESULTS AND DISCUSSION

There were 136,046 CHARS records and 76,112 WTR records in the full samples (not restricted to work-related injuries). Figure 2 depicts the ratio of the number of traumatic injury-related hospital discharges captured by the WTR to that captured by CHARS, for each included year. There was a 34% increase in the ratio during the first four years, from 0.41 in 1998 to 0.55 in 2001; in comparison, the ratio increased less than 9% during the next eight years, from 0.57 in 2002 to 0.62 in 2009.

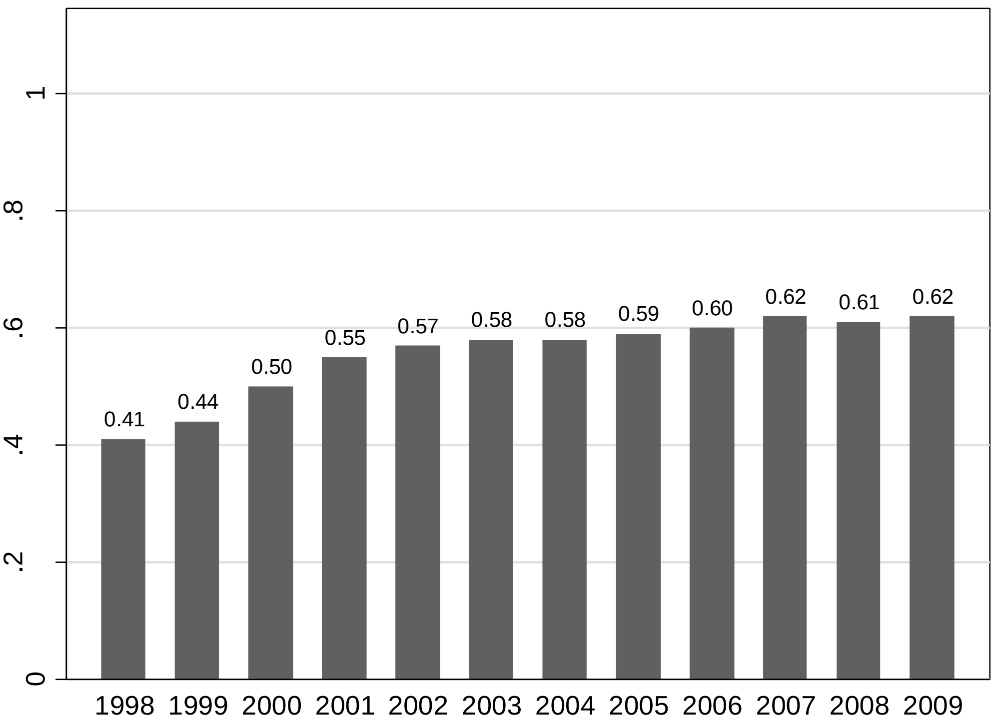

Figure 2. Annual ratio of the number of traumatic injury-related hospital discharges captured by the WTR to that captured by CHARS (not restricted to work-related injuries).

CHARS contained 14,091 work-related injuries, and 4,461 (32%) of those were severe. The WTR contained 7,127 work-related injuries, and 4,081 (57%) of those were severe. Payer was missing for 0.01% of CHARS records overall, and for less than 0.1% in every year. Payer was missing for 3.4% of WTR records overall, but notably for 5.6% in 2002, 13.1% in 2003, and 7.7% in 2004. The work-related field was missing for 2.1% of WTR records overall; 3% or less in every year, except for 5.6% in 1998.

Figure 3 depicts age-adjusted rate estimates and nonlinear trends based on CHARS and WTR data for all eligible work-related traumatic injuries. Figure 4 depicts the same information for the subset of severe injuries. The vertical capped bars depict 95% gamma confidence intervals. On visual inspection, nonlinear trends based on WTR rate estimates closely tracked those based on CHARS (i.e., vertical difference between rate estimates was stable over time), beginning approximately in 2002. When restricted to severe injuries (Figure 4), WTR and CHARS rate estimates had overlapping confidence intervals in every year from 2000 through 2008.

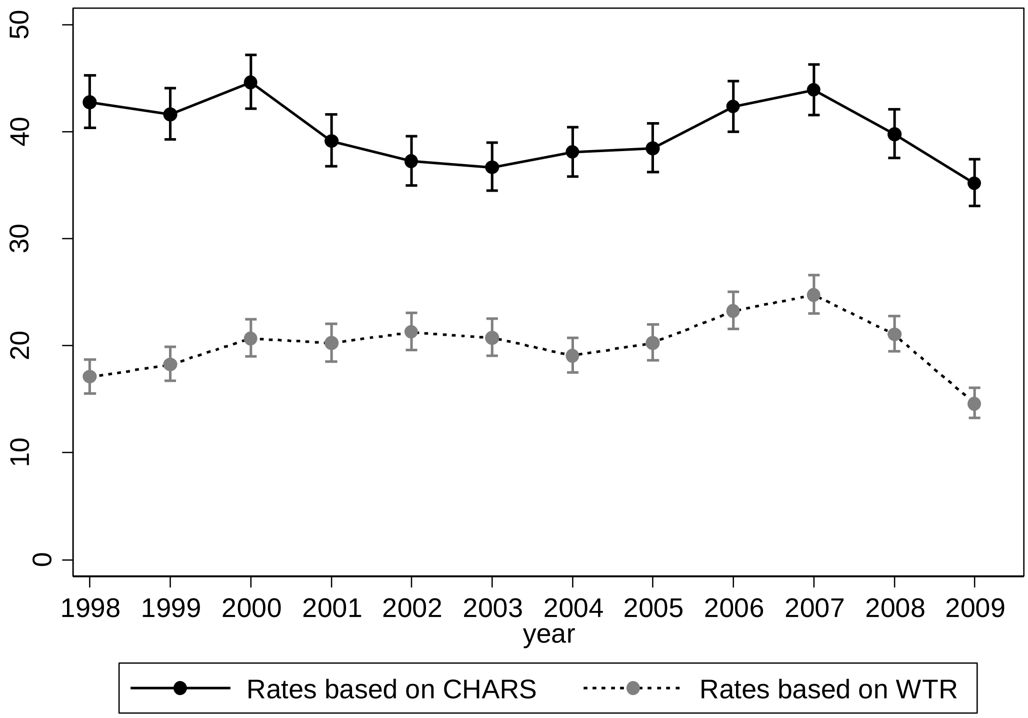

Figure 3. All work-related injuries: age-adjusted rates and 95% confidence intervals using CHARS and WTR.

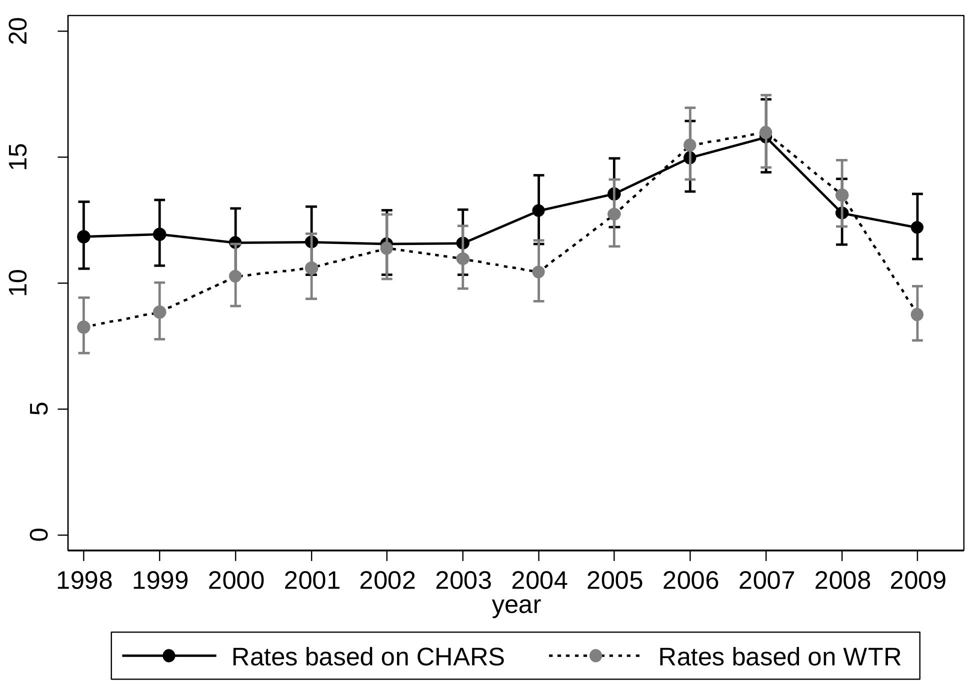

Figure 4. Severe work-related injuries: age-adjusted rates and 95% confidence intervals using CHARS and WTR.

Table 11 presents estimates of linear trends in age-adjusted injury rates based on CHARS and WTR data, for all injuries and for severe injuries. Trend estimates differed somewhat by data source; however, confidence intervals were substantially similar, and general conclusions regarding whether work-related injury rates were significantly increasing over time (or were statistically flat) were the same using either data source.

Table 11. Linear trends in age-adjusted rates by data source and sample

Sample and data source	1998-2009			2002-2009		
	Annual % change	p-value	95% CI	Annual % change	p-value	95% CI
All injuries						
CHARS	0.7↓	NS	1.8↓, 0.4↑	0.7↑	NS	1.4↓, 2.8↑
WTR	0.7↑	NS	1.5↓, 2.9↑	1.5↓	NS	5.7↓, 2.8↑
Severe injuries						
CHARS	1.8↑	0.01	0.4↑, 3.3↑	2.0↑	NS	1.1↓, 5.2↑
WTR	3.9↑	0.008	1.0↑, 6.9↑	1.4↑	NS	4.4↓, 7.7↑

We found substantial similarity between occupational injury trends estimated using either WTR or CHARS data. It is important to recognize that overlapping but somewhat distinct populations and types of injuries are captured by each data source. Hospital discharge databases, including CHARS, typically include all or nearly all community hospitals in a particular state, while trauma registries typically include a subset of reporting trauma facilities, and not every traumatic injury treated at those facilities would qualify for inclusion in the registry. When we restricted the sample to severe injuries to enhance comparability, we observed more similarity across the two data sources in injury rates. (The difference in severe injury rate estimates for 2009 across the two data sources was most likely due to random variation; we were unable to identify a probably cause.) Different methods were used to identify work-related injuries in each data set, and it is perhaps most remarkable that so little difference was observed.

It is also important to recognize that the incidence of occupational injury hospitalizations will be underestimated using either data source. In the case of CHARS, work-related injuries will not be counted if WC is not identified as the primary payer. In the case of the WTR, work-related injuries will not be counted if they are not identified by hospital personnel as being work-related, do not meet WTR reporting criteria, or are treated at non-reporting hospitals.

Especially in the early years, the WTR staff were focused on training trauma registrars and improving the completeness and quality of reporting. There were also changes to inclusion criteria, and changes in the number of reporting trauma facilities as hospitals achieved trauma designation. As reflected by the increasing ratio of all injuries captured by the WTR compared to CHARS (Figure 2), it appears that the WTR was still maturing through approximately 2001, about 7 years after inception. This is consistent with other research showing that trauma systems take about ten years to fully mature.[100] However, linear trend estimates did not substantially differ across the two data sets, whether the years 1998 through 2001 were included or excluded from the trend models. As shown in Figures 3 and 4, linear trend estimates are a rough approximation and are sensitive to the specific start and end years selected. Though linear trend estimates are commonly used as a summary measure, occupational injury trends are not always linear in nature, and tend to track economic cycles even after adjusting for the underlying employed population. Despite the results of the linear trend regression models, Figures 3 and 4 suggest that injury rates and trends estimated using the WTR are likely to be more accurate reflections of underlying injury incidence if restricted to approximately 2002 forward.

Restricting the sample to severe injuries provided a different and less optimistic picture of occupational injury trends than did using all injuries. This is consistent with our previous research suggesting that occupational injuries are not trending downward to the degree suggested by studies based on employer surveys or WC claims data. [14,101] Observed trends in severe injuries are less likely to be affected by temporal trends in hospital admission practices than are minor injuries, and thus more reflective of general trends in underlying injury incidence.[30,101]

Hospital discharge databases and trauma registries each offer a distinct set of strengths and limitations. Hospital discharge databases are typically population-based, and many are publically available, but they are constructed for billing and reimbursement purposes. Hospital discharge records are generally only available for non-federal, acute care hospitals. The WTR and many other trauma registries are better resourced, have more clinical input and validation, and contain more accurate and complete injury information, but they are not typically population-based.

Hospital discharge records do not contain specific information about whether the hospitalization was work-related (other than payer), limiting utility for occupational injury research. Use of WC as payer is known to undercount work-related injuries.[49,50] In addition, the expected payer on hospital discharge records may not be accurate and may not reflect the actual payer. The WTR also has limitations for occupational injury surveillance related to narrowly defined inclusion criteria and incomplete trauma coverage, as well as changes over time in both. However, unlike CHARS, the WTR does contain specific information about whether an injury was work-related.

Trauma registries undergo ongoing oversight and scrutiny, and require significant hospital commitment.[102] Greater resources are devoted to coding trauma registry records compared with hospital discharge records, including more input from clinical staff.[102] In addition, trauma charts are often abstracted concurrently (during the inpatient stay), providing more opportunity to update and correct data before discharge.[102] As a case in point, the WTR has conducted periodic validation studies assessing factors such as coding accuracy. The software used by the hospitals to collect and submit data to the WTR contains logic checks and error checks that facilitate data quality and completeness. The WTR has worked to improve reporting over time, which is reflected in the small amounts of missing data for most data fields. However, trauma registries are also more directly affected by human factors, e.g., changes in trauma registrars and documentation practices within and between hospitals over time.

Trauma registries are focused on complete coding of injury-related diagnoses and severity measures, which are used to guide clinical management and evaluation. The AIS severity scores contained in the WTR were generally assigned by the trauma registrars, based on injury documentation by the trauma surgeons and other clinicians. In contrast, the ICD-9-CM codes in hospital discharge data were generated primarily for billing and reimbursement purposes by medical records or coding personnel at each facility (usually not clinical staff); to maximize potential reimbursement, billing optimization software is also typically used. The need to use software to estimate AIS scores from ICD-9-CM diagnosis codes introduces an additional approximation and potential source of error when using hospital discharge data. In a previous study using a set of linked WTR and WC records, we found moderate agreement between the ISS contained in the WTR and those estimated from WC billing data using -icdpic- (kappa=0.43).[59] Yet despite ample sources of error, injury severity measures estimated from administrative databases have been found useful for predicting work disability and cost outcomes.[59,60]

SPECIFIC AIM 3: ***Link WTR and Washington State hospital discharge data to assess concordance for data fields particularly relevant to occupational health services research, including payer, race/ethnicity, severity, fatality data, and ICD-9-CM external cause of injury codes (E-codes). Use the linked data to evaluate E-code based methods of identifying work-related injuries in hospital discharge records.***

This aim was successfully completed (further details and a full presentation of results can be found in publication #2 in the list of publications). We found at least moderate agreement between WTR and CHARS for every data field and constructed measure that we compared. Although we found that injury severity was underestimated using CHARS, the differences were relatively small. Thus, injury severity estimated from hospital discharge records may offer an improvement over having no available injury severity measures or relying on downstream proxies such as length of inpatient stay. Several studies have focused heavily on shortcomings of hospital discharge data relative to trauma registry data, however this study and others have found substantial agreement for key data fields, enough to support the use of hospital discharge records in appropriate circumstances. This study provided further validation for the use of payer to identify work-related injuries, but also confirmed that many work-related injuries could not be identified using payer or E-code fields. In addition, this study's findings suggest that place of injury E-codes (E849.X) are valuable for the identification of occupational injuries.

METHODOLOGY

Data sources and study population

As for Aim 2, data for traumatic injury-related inpatient hospital discharges were obtained from the WTR and CHARS. CHARS records were limited to those from designated WTR reporting hospitals, and to hospitalizations which had at least one ICD-9-CM injury-related diagnosis (range: 800-959.9) in any of the 25 available diagnosis fields. Data were limited to 2009 for this aim, due to restricted availability in previous years of the personal identifiers needed for linkage procedures. Direct personal identifiers (i.e., name, date of birth, gender, last four digits of the Social Security number) were available for the linkage procedures. Records were linked and deduplicated at the individual level using The Link King, a public domain software program developed in Washington State for probabilistic and deterministic linkage of administrative records.[88,103] All non-exact matches were reviewed by the first author for plausibility. Within unique deduplicated individual patients, records for a specific hospital discharge were then linked across the WTR and CHARS databases by requiring an exact match on discharge hospital and discharge date (some patients had multiple hospital discharges).

Measures

The linked discharge records were used to assess concordance between WTR and CHARS records for data fields particularly relevant to occupational health services research, including payer, race, ethnicity, inpatient death, estimated injury severity, and standard injury descriptors based on E-codes, i.e., external cause of injury, manner/intent of injury, and place of injury. For detailed information about each data element, the reader is referred to the WTR data dictionary,[104] and the CHARS data dictionary,[105] each available online.

Data fields were recoded as necessary to be comparable across data sources. Primary payer varied somewhat across data sources in the level of detail and categories available. For comparability across data sources, primary payer was recoded into a five-category variable (Medicare, Medicaid, WC, other insurance, uninsured). A second binary payer variable (WC, non-WC) was also constructed. This enabled comparison of payer data from each data source at two different levels of detail.

The variable indicating race was also coded differently across data sources; for comparability, we recoded race into a four-category variable (white, Black/African-American, Asian/Pacific Islander, American Indian/Alaska Native). The "other" category in the WTR (N=416; 3.8%) and the "multiple" category in CHARS (N=1; 0.01%) were recoded as missing since they could not be directly compared or collapsed into other categories.

Injury mechanism classifications were based on the primary E-code, after cleaning as recommended by the State and Territorial Injury Prevention Directors Association/Safe States Alliance (e.g., replacing any E849 place of injury codes in the primary E-code field with valid E-codes in subsequent fields; see Step 3 on page 9 of the citation).[82] External cause of injury categories and manner/intent of injury categories were constructed as recommended in injury surveillance guidance promulgated by the Centers for Disease Control and Prevention (CDC).[106] There were two E-code fields in the WTR and a separate place of injury field. Place of injury for CHARS was constructed using the E849 code listed first among all seven E-code fields contained in CHARS. Place of injury (E849) is particularly relevant to occupational injury research because it enables identification of injuries occurring at industrial/mine/quarry locations.

The Abbreviated Injury Scale (AIS) was used to classify injury severity. [52] We focused on two recognized ordinal measures of injury severity: (1) Injury Severity Score (ISS), which has been well-validated for the prediction of mortality[54] and remains the most common measure of injury severity used by trauma systems and in trauma research, and (2) the overall maximum AIS (MaxAIS), which performs as well as the ISS in at least some circumstances.[57,58] MaxAIS ranges from 1 (minor) to 6 (maximal), and is a measure of the most severe injury. ISS is the sum of squares of the highest AIS scores from up to three different body regions, providing a cumulative severity measure for multiple injuries. ISS has a range of 1 to 75, with 75 assigned whenever MaxAIS is equal to 6. We categorized ISS using the standard scheme of minor (1-8), moderate (9-15), and major (16-75). These two scores are present as data fields in the WTR, having been calculated either by the trauma registrar or by the trauma registry software. For CHARS, these scores were estimated from all 25 available ICD-9-CM diagnosis codes using -icdpic-.

Work-related injuries

In contrast to hospital discharge databases, the WTR contains a data field that can be used to directly identify work-related injuries, independently of payer. This work-related indicator has been shown to be highly sensitive (87%) and specific (97%) in identifying work-related injuries.[50] The WTR work-related indicator was used as a gold standard to assess two different approaches to the identification of work-related injuries in hospital discharge data, expected payer and E-codes.

Despite the widespread use of primary expected payer to identify work-related injuries in hospital discharge records (e.g., the practice is recommended by CSTE for constructing state-based Occupational Health Indicators[35]), there have been few studies assessing the validity of that practice; to our knowledge, there have been none in Washington State. Washington has a single payer WC system for the approximately 70% of workers covered by the Washington State Department of Labor and Industries (L&I) State Fund, as specified by the Industrial Insurance Act.[87] Self-insured employers account for the other 30%. L&I performs the functions of an insurer for State Fund claims, and administers the state WC system for both State Fund and self-insured employers. However, the covered population does not include federal employees or exempt/excluded employment (e.g., sole proprietors, domestic workers, etc.). The L&I payer category captures both State Fund and self-insured WC coverage.

As stated earlier, E-codes are used to capture the circumstances and external cause of an injury. In a Canadian study, Alamgir et al., developed a list of E-codes that could be used to identify work-related injuries based on the type of injury (e.g., powered vehicles used solely within industrial and commercial buildings/premises), the person to whom the injury occurred (e.g., railway employee, crew), and/or the place the injury occurred (e.g., nonresidential farm premises, mine, industrial site).[107] We constructed a similar indicator for this study, except that injuries were not considered work-related based solely on presence of an E-code indicating that the injury occurred on nonresidential areas of a farm (i.e., E849.1 was not used). This decision was based on our previous work regarding the presence of false positives and questionable face validity for this particular criterion.[50]

In all, we constructed four binary indicators of work-relatedness, as shown in Table 12: (1) Payer=WC, set to 1 if the primary expected payer in CHARS was L&I; (2) E=work, based on work by Alamgir et al.,[107] and further refined as shown in Table 1; (3) E=0000, set to 1 if any CHARS E-code field contained the code E000.0 (civilian activity done for income or pay); and (4) E=0000/work, a combined indicator, set to 1 if either E=work or E=0000 indicated a work-related injury. Because the E-code E000.0 only became available for use beginning October 1, 2009, the E=0000 and E=0000/work indicators were tested only among linked records having a discharge date during the last calendar quarter of 2009.

Table 12. Work-related indicators based on CHARS hospital discharge data

Indicator	Description
Payer=WC	Primary expected payer listed as Washington State Department of Labor and Industries (WC)
E=work	Presence of E849.2 or E849.3 (place of injury: industrial, mine, or quarry) OR any of the following E-codes: E800–E807 with 4th digit = 0 (railway; railway employee) E830–E838 with 4th digit = 2 or 6 (water transport; crew or dockers/stevedores) E840–E845 with 4th digit = 2 or 8 (air/space transport; crew or ground crew) E846 (powered vehicles used solely on industrial/commercial premises)
E=0000	E000.0 present in any E-code field; limited to patients discharged on/after 10/1/2009 (when this E-code became available)
E=0000/work	Presence of either E=0000 or E=work; limited to patients discharged on/after 10/1/2009

CHARS, Comprehensive Hospital Abstract Reporting System; WC, workers' compensation.

Data analysis

Cohen's kappa was used to calculate chance-corrected agreement between WTR and CHARS data fields.[108] Weighted kappa was used to assess concordance for the two ordinal variables, MaxAIS and ISS. In each case, adjacent categories were counted as 50% correct (given a weight of 0.5), and non-adjacent categories were considered 100% incorrect. To evaluate kappa, we used qualitative guidelines based on recommendations by Landis and Koch: (a) 0–0.20 was considered as slight agreement, (b) 0.21–0.40 as fair, (c) 0.41–0.60 as moderate, (d) 0.61–0.80 as substantial, and (e) 0.81–1 as almost perfect agreement.[91]

To assess whether conclusions related to attributable cause distribution might differ based on which data source was used for surveillance (WTR or CHARS), the external cause of injury categories were ordered in descending frequency for each source separately. This analysis excluded the three nonspecific cause categories (i.e., Other specified, classifiable; Other specified, not elsewhere classifiable; and Unspecified) and cases with no valid E-codes.

The linked records were used to evaluate the sensitivity, specificity, and positive and negative predictive values of the four payer and E-code based work-related indicators, using the WTR work-related field as the gold standard. Although positive/negative predictive values are dependent on prevalence, the prevalence of work-related injuries in our data set should be roughly similar to that in other state hospital discharge databases and trauma registries. Discriminatory performance of the indicators was assessed using receiver operating characteristic (ROC) curve techniques, specifically the area under the ROC curve (AUC). This measure has the advantage of summarizing sensitivity and specificity using a single number, and is useful when it is desirable to weight sensitivity and specificity equally.[109] To evaluate AUC, we used qualitative guidelines based on recommendations by Hosmer and Lemeshow: (a) if AUC = 0.5, the test has no discrimination, (b) 0.5 < AUC < 0.7, poor discrimination, (c) 0.7 ≤ AUC < 0.8, acceptable discrimination, (d) 0.8 ≤ AUC < 0.9, excellent discrimination, and (e) AUC ≥ 0.9, outstanding discrimination.[110] All statistical tests were two-tailed, with statistical significance defined as p≤0.05. Analyses were performed using Stata/MP 13.0 for Windows.[111] The Stata user-written program -diagt- was used to calculate sensitivity, specificity, predictive values, and AUC statistics.[112]

RESULTS AND DISCUSSION

Data linkage procedures resulted in an analytic data set containing 10,943 linked discharges from 59 hospitals. Of the eligible WTR discharges, 86.0% were linked to a CHARS record; conversely, 32.2% of the eligible CHARS discharges were linked to a WTR record. WTR records indicated that 491 (4.5%) of the linked discharges were work-related. Table 13 presents injury severity measures based on each data source. The median MaxAIS score was 3 using either source, but mean MaxAIS was 2.6 using CHARS records and 2.9 using WTR records. The median uncategorized ISS was 9 using either source, but mean ISS was 9.6 using CHARS records and 12.2 using WTR records.

Table 13. Injury severity measures

Injury severity measure	WTR (N=10,934)		CHARS (N=10,610)	
	N	%	N	%
Maximum Abbreviated Injury Scale (MaxAIS)				
Minor (1)	707	6.5	719	6.8
Moderate (2)	2,740	25.1	4,206	39.6
Serious (3)	5,137	47.0	4,237	39.9
Severe (4)	1,585	14.5	1,272	12.0
Critical (5)	719	6.6	160	1.5
Maximal (6)	46	0.4	16	0.2
Injury Severity Score (ISS)				
Minor (1-8)	3,232	29.6	4,594	43.3
Moderate (9-15)	4,741	43.4	3,989	37.6
Major (16-75)	2,961	27.1	2,027	19.1

WTR, Washington State Trauma Registry; CHARS, Comprehensive Hospital Abstract Reporting System.

Table 14 presents the results of concordance testing, as well as the amount of missing data for each data field by data source. Ethnicity and race were often missing in both sources. Although E-codes were present for 98.6% of CHARS records, place of injury could be determined for only 18.2%. The remaining data fields of interest had only small amounts of missing data in either source.

After cleaning, 58.6% of the full primary E-codes matched exactly across data sources and 67.7% of primary E-codes trimmed to the first three numerical digits matched exactly. Agreement was at least moderate for every data field assessed. Agreement between WTR and CHARS records was almost perfect for race, external cause of injury, manner/intent of injury, and inpatient death. Substantial agreement was observed for primary payer and ISS. Moderate agreement was observed for place of injury and MaxAIS. Although kappa indicated only moderate agreement for ethnicity, observed agreement was over 95%.

Table 14. Data field concordance between WTR and CHARS

Data field	kappa	N for kappa	Observed agreement	Expected agreement	Missing data (%) in WTR	Missing data (%) in CHARS
Ethnicity	0.517	5,524	95.7%	91.2%	2,829 (25.9%)	3,478 (31.8%)
Race	0.877	7,697	97.6%	80.3%	1,437 (13.1%)	2,655 (24.3%)
Primary payer	0.744	10,892	82.1%	30.0%	51 (0.5%)	0
Primary payer=WC	0.787	10,892	98.0%	90.4%	51 (0.5%)	0
Cause (all 18 categories)	0.884	10,469	92.4%	34.6%	11 (0.1%)	468 (4.3%)
Cause (15 categories)*	0.915	10,073	94.6%	36.9%	11 (0.1%)	468 (4.3%)
Manner/intent of injury	0.901	10,468	98.4%	84.2%	11 (0.1%)	468 (4.3%)
Place of injury†	0.556	1,975	69.2%	30.7%	156 (1.4%)	8,955 (81.8%)
Inpatient death	0.996	10,943	99.9%	92.7%	0	0
MaxAIS (six categories)‡	0.554	10,602	78.4%	53.8%	9 (0.1%)	333 (3.0%)
ISS (three categories)‡	0.610	10,602	83.7%	58.4%	9 (0.1%)	333 (3.0%)

*Excludes the three nonspecific cause categories (Other specified, classifiable; Other specified, not elsewhere classifiable; Unspecified) and cases with no valid E-codes.
†Derived from E849.X codes for CHARS, but from a separate place of injury field for the WTR.
‡Weighted kappa.
WTR, Washington State Trauma Registry; CHARS, Comprehensive Hospital Abstract Reporting System.

Falls and motor vehicle traffic were the primary and secondary attributable cause of injury respectively, using either WTR or CHARS records. There was no difference in ordering for the most frequent eight causes (accounting for 97% of specifically classified injuries), though ordering of the less frequent causes (each accounting for less than 1% of injuries) did vary by source.

Using the WTR work-related field as the gold standard, four methods of identifying occupational injuries in CHARS hospital discharge data were assessed (Table 15). Sensitivity was 76.0% for the payer-based indicator, but under 14% for all three E-code based indicators. The payer-based indicator provided excellent discrimination of work-related injuries (using AUC), but all three E-code based indicators provided poor discrimination. On the other hand, the E-code based indicators had very high specificities (upwards of 99%), even higher than did the payer-based indicator (97.8%). Positive predictive values were roughly similar for all four indicators (ranging from 57.1% to 68.6%), as were negative predictive values (ranging from 95.8% to 98.9%). There was slight agreement between Payer=WC and E=work (kappa=0.118), with little overlap in the cases identified by each indicator.

Table 15. Identification of work-related injuries using CHARS-based indicators (gold standard: WTR work-related data field)

Indicator	True+	AUC	Sensitivity		Specificity		PV+		PV-	
	N		%	95% CI	%	95% CI	%	95% CI	%	95% CI
Payer=WC	373	0.87	76.0	71.9 - 79.7	97.8	97.5 - 98.1	62.0	57.9 - 65.9	98.9	98.6 - 99.1
E=work	35	0.53	7.1	5.0 - 9.8	99.8	99.8 - 99.9	68.6	54.1 - 80.9	95.8	95.4 - 96.2
E=0000*	8	0.53	7.2	3.2 - 13.7	99.8	99.5 - 99.9	57.1	28.9 - 82.3	96.0	95.2 - 96.7
E=0000/work*	15	0.57	13.5	7.8 - 21.3	99.6	99.3 - 99.8	62.5	40.6 - 81.2	96.2	95.4 - 96.9

*Sample restricted to the 2,581 discharges on/after 10/1/2009, when E000.0 became available for use.
CHARS, Comprehensive Hospital Abstract Reporting System; WTR, Washington State Trauma Registry; AUC, area under the receiver operating characteristic curve; PV, predictive value; CI, confidence interval; WC, workers' compensation. Indicator descriptions are presented in Table 12.

We found at least moderate agreement between WTR and CHARS for every data field and constructed measure that we compared. There was no meaningful difference between WTR and CHARS regarding ordering of attributable cause. Nearly 60% of the full primary E-codes matched exactly across data sources, comparing favorably with an Arkansas study of transport-related injuries that demonstrated exact matches on full primary E-codes for 39% of linked trauma registry and hospital discharge records.[102] After classifying injuries into E-code based categories, agreement between WTR and CHARS records was almost perfect for external cause of injury and manner/intent of injury, comparing favorably with a Maryland study that found substantial agreement between linked trauma registry and hospital discharge records regarding mechanism of injury.[113]

There were only small amounts of missing data (<5%) for most data fields in either data source, with the exception of place of injury in CHARS (discussed relative to aim 2 below), and race and ethnicity in both sources. CHARS first began to include race/ethnicity data in 2007, and completeness may improve over time. Although the WTR has included race/ethnicity fields since inception, missing data remain a challenge, and reporting practices vary by hospital. For example, ethnicity was a required element in the WTR software used by reporting hospitals (and could not be skipped), but ethnicity could be recorded as "Hispanic origin" (any race), "Non-Hispanic origin" (any race) or "Unknown." Some reporting hospitals had a practice of almost exclusively selecting "Unknown." Due to lack of validation, inconsistent hospital reporting practices, and high percentages of missing data, WTR staff have been reluctant to rely on WTR-based race/ethnicity data for reporting purposes. Despite these issues, observed agreement for ethnicity was nearly 96% for the subset of cases for which an ethnicity was reported in both the WTR and CHARS. However, Latinos/Hispanics were undercounted when using 2009 CHARS data, relative to using the WTR.

We found that injury severity was underestimated using CHARS, which comports with findings from other studies comparing trauma registry and hospital discharge records.[113-115] Mean MaxAIS and mean ISS were higher when based on WTR records, compared with CHARS records. However, median MaxAIS and ISS scores were the same using either data source, and weighted kappa indicated moderate agreement for MaxAIS and substantial agreement for ISS. It has been argued that because the average differences in injury severity derived from trauma registries compared with administrative databases are relatively small, the estimated measures may be adequate for many purposes.[59,113] It is worth noting that the ISS category distribution produced using CHARS is quite different than the distribution produced using the WTR (Table 13), which may have policy implications. It is not surprising that CHARS would underestimate injury severity relative to the WTR. Trauma registries are focused on complete coding of injury-related diagnoses and severity measures, which are used to guide clinical management and evaluation. The AIS severity scores contained in the WTR were generally assigned by the trauma registrars, based on injury documentation by the trauma surgeons and other clinicians. In contrast, the ICD-9-CM codes in hospital discharge data were generated primarily for billing and reimbursement purposes by medical records or coding personnel at each facility (usually not clinical staff). The use of software to estimate AIS scores from ICD-9-CM diagnosis codes introduces an additional approximation and potential source of error when using hospital discharge data. In a previous study using a set of linked WTR and WC records, we found moderate agreement between the ISS contained in the WTR and the ISS estimated from WC billing data using -icdpic- (kappa=0.43).[59] Yet despite ample sources of error, injury severity measures estimated from administrative databases have been found useful for predicting work disability and cost outcomes.[59,60]

We also assessed the validity of using payer or E-codes to identify work-related injuries in hospital discharge records. Sensitivity was 76% for the payer-based indicator, but very low for all three E-code based indicators (under 14%). The payer-based indicator provided excellent discrimination of work-related injuries (using AUC, which weights sensitivity and specificity equally), but all three E-code based indicators provided poor discrimination. On the other hand, the E-code based indicators had very high specificities (upwards of 99%), higher than the payer-based indicator. Although E-codes alone are not adequately sensitive for occupational injury surveillance purposes, the high specificities and negative predictive values of the E-code based indicators suggest they may be useful for research contexts where identifying a specific subset of work-related injuries independently of payer is more important than complete case capture.

Place of injury E-codes (E849.X) enable identification of industrial, mine, and quarry locations. Although E-codes were present for 99% of CHARS records, place of injury could be determined for only 18%. This very likely drove the low sensitivity of the E-code based indicators. In general, E-codes are prevalent in hospital discharge records; for example, only 9% of injury-related hospital discharge records provided to Healthcare Cost and Utilization Project (HCUP) for 2010 did not contain an injury E-code.[81] Many states encourage E-code reporting through the use of mandates, enforcement, or other strategies.[42] However, expectations for use of the place of injury E-codes (E849.X) vary across states. According to injury surveillance guidance that prioritizes mechanism over place of injury, place of injury is not considered a valid primary E-code; hence, place of injury cannot be captured when only one E-code field is available.[82] It is quite possible that the E-code based indicators would be more sensitive and thus more useful in states with a higher prevalence of E849.X codes. Research using hospital discharge databases from other states would be required to address this possibility. We also considered V62.1 (adverse effects of work environment) and V71.3 (observation following accident at work) for use as an indication of work-relatedness, but there were no instances of either code in either the WTR or CHARS diagnosis fields. The underutilization of E000.0 (civilian activity done for income or pay) represents a lost opportunity to identify work-related injuries. In an internal study using linked WTR/CHARS data from 2009 through 2011, WTR staff found no indication that either the usage or sensitivity of E000.0 has increased since its initial introduction in fall of 2009 [unpublished data, Z. Shorter, 2013]. Data available online for the Nationwide Inpatient Sample (via HCUPnet[116]) also do not indicate frequent or increasing use of the E000.0 code since its introduction. Although it remains to be seen, the impending introduction of the ICD-10-CM lexicon may also hold promise for improving capture of work-related injuries. The code Y99.0 (civilian activity done for income or pay) in the ICD-10-CM lexicon is similar to E000.0 in the ICD-9-CM lexicon.

This study provides further validation for the use of payer to identify work-related injuries. Although sensitivity was only 76%, somewhat lower than the 83% sensitivity estimated by the

Sorock et al. study,[49] it was still markedly higher than for the E-code based methods. It would not be reasonable to expect payer to approach 100% sensitivity, given that many injuries are not covered by WC, even if reported as work-related (e.g., federal employment, exempt/excluded employment). Though specificity was very high, and payer remains the most viable proxy in the absence of direct information about work-relatedness, using payer fields to identify work-related injuries is also known to be problematic for surveillance due to temporal trends in hospital billing practices and WC coverage.[70] Finally, we found only slight agreement between payer and the E-code based indicator (E=work), with little overlap in identified cases. This suggests that a combined indicator might be useful in some circumstances.

Of the eligible WTR records, 86% were linked to a CHARS record. Similar studies have linked upward of 90% of trauma registry records to hospital discharge records; for example, 99.9% in Arkansas[102] and 93% in Maryland.[113] Our linkage strategy was designed to produce a high certainty level for the matches ultimately included in the linked data set, but may have resulted in some under-matching due to requiring an exact match on discharge date.

Conversely, 32% of the eligible CHARS discharge records linked to a WTR record. In the Maryland study, researchers linked 53% of hospital discharge records to trauma registry records; however, they first restricted eligible discharge records to those likely to meet trauma registry criteria.[113] In order to maximize the number of possible linkages for our study, we did not attempt to construct a WTR-eligible CHARS sample prior to linkage procedures, other than to restrict the CHARS records requested to those having at least one injury diagnosis.

CONCLUSIONS

We assessed the impact of severity restriction on injury rate trend estimates nationally and for nine separate states. 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 standard occupational health indicators (OHIs) for state-based surveillance that can be implemented using existing state data.[35,39] 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.[27] However, hospitalizations are quite heterogeneous (e.g., injury, illness, surgery). We developed a new occupational health surveillance indicator (OHI #22 Work-Related Severe Traumatic Injury Hospitalizations) that includes a standardized definition of traumatic injury to reduce heterogeneity and incorporates a severity threshold. Severe traumatic injuries may prove to be a more consistent bellwether of work-related injury trends than all hospitalizations.[30]

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.

We found evidence of substantial multi-state disparities in occupational injury-related hospitalizations. Further research is needed to identify and address the underlying causes of these disparities. The ability to identify populations at increased risk is crucial for guiding prevention planning. However, hospital discharge databases do not contain information about occupation or industry, restricting their value for identifying specific prevention opportunities. This study highlights the potential utility of including occupation, industry, and other work-related information in hospital discharge databases, in order to enhance surveillance and prevention efforts.

In an effort to address the pressing need for better injury severity measures for occupational health services research,[59,101,117] we have described a new method of identifying severe traumatic injuries that does not require special software, predictive models, or data on mortality or long-term outcomes. This study demonstrated that a severe injury indicator, based on an existing list of ICD-9-CM diagnosis codes for severe traumatic injuries, was a significant predictor of work disability, medical intensity, and medical costs. This severe injury indicator can potentially be used in a variety of ways for occupational injury surveillance and research. For example, it could be used as a method of risk adjustment or to control for confounding in intervention, program evaluation or outcome studies. It could also be used as a vehicle for imposing a severity restriction for purposes of constructing comparison groups or constructing case definitions for surveillance. This method provides a simple and transparent alternative to AIS-based injury severity estimation.

This study found substantial similarity between occupational injury trends estimated using either trauma registry or hospital discharge data, despite the somewhat different populations and injury types represented. Rate estimates differed by data source, and were most similar when a severity threshold was applied. In the case of Washington State, trauma registry maturity for the purpose of estimating injury rates and trends occurred about seven years after inception. We concluded that a mature state trauma registry with mandatory reporting requirements can be used as an alternative to population-based hospital discharge data for surveillance of severe work-related traumatic injuries, while acknowledging that the incidence of occupational injury hospitalizations will be underestimated using either data source.

We found at least moderate agreement between WTR and CHARS for every data field and constructed measure that we compared. Although we found that injury severity was underestimated using CHARS, the differences were relatively small. Thus, injury severity estimated from hospital discharge records may offer an improvement over having no available injury severity measures or relying on downstream proxies such as length of inpatient stay.[53,59,113] Several studies have focused heavily on shortcomings of hospital discharge data relative to trauma registry data,[114,115,118] however this study and others have found substantial agreement for key data fields,[102,113] enough to support the use of hospital discharge records in appropriate circumstances.

This study provided further validation for the use of payer to identify work-related injuries, but also confirmed that many work-related injuries could not be identified using payer or E-code fields. It is difficult to obtain information about injured workers who do not have WC listed as a payer, whether that be due to billing practices, access barriers or excluded/exempt employment. The WTR work-related field provides an unusual opportunity to describe this population; however, the lack of occupation and industry information restricts what can be learned. We recommend that trauma registries and hospital discharge databases add occupation, industry, and work status as required fields, both to improve surveillance and research efforts as well as to guide policy and prevention efforts. In the meantime, this study's findings suggest that place of injury E-codes (E849.X) are valuable for the identification of occupational injuries and their use (as a secondary E-code or separate data field) should be expanded. The appropriate use of E000.0, and Y99.0 when the ICD-10-CM lexicon is introduced, should also be encouraged.

Linkage of trauma registry and hospital discharge records offers opportunities for data field validation and new lines of research. While details of these data sources vary state-by-state, and there is clearly a need to extend validation research into more states, this study contributes to understanding the strengths and limitations of each data source. Expanded use of trauma registry and hospital discharge data could contribute to planning and evaluation of occupational injury prevention programs, improved case ascertainment for severe occupational injuries, and identification of high-risk populations and emerging injury patterns.

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Using Injury Severity to Improve Occupational Traumatic Injury Trend Estimates

Total Enrollment: 103,763 from **CHARS database** **Protocol Number:** N/A

Grant Number: 5R21OH010307-02

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race

Ethnic Category	Sex/Gender Females	Males	Unknown or Not Reported	Total	
Hispanic or Latino	292	545	0	837	**
Not Hispanic or Latino	16,137	15,659	0	31,796	
Unknown (individuals not reporting ethnicity)	33,874	37,256	0	71,130	
Ethnic Category: Total of All Subjects*	50,303	53,460	0	103,763	*
Racial Categories					
American Indian/Alaska Native	315	409	0	724	
Asian	469	412	0	881	
Native Hawaiian or Other Pacific Islander	312	275	0	587	
Black or African American	363	776	0	1,139	
White	18,040	16,639	0	34,679	
More Than One Race	1	6	0	7	
Unknown or Not Reported	30,803	34,943	0	65,746	
Racial Categories: Total of All Subjects*	50,303	53,460	0	103,763	*

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)

Racial Categories	Females	Males	Unknown or Not Reported	Total	
American Indian or Alaska Native	2	0	0	2	
Asian	0	1	0	1	
Native Hawaiian or Other Pacific Islander	10	17	0	27	
Black or African American	3	2	0	5	
White	142	258	0	400	
More Than One Race	0	0	0	0	
Unknown or Not Reported	135	267	0	402	
Racial Categories: Total of Hispanics or Latinos**	292	545	0	837	**

* These totals must agree.
** These totals must agree.

Inclusion Enrollment Report

This report format should NOT be used for data collection from study participants.

Study Title: Using Injury Severity to Improve Occupational Traumatic Injury Trend Estimates

Total Enrollment: 155,244 from **WTR database** **Protocol Number:** N/A

Grant Number: 5R21OH010307-02

PART A. TOTAL ENROLLMENT REPORT: Number of Subjects Enrolled to Date (Cumulative) by Ethnicity and Race

Ethnic Category	Sex/Gender				
	Females	Males	Unknown or Not Reported	Total	
Hispanic or Latino	1,755	6,208	0	7,963	**
Not Hispanic or Latino	38,032	60,721	3	98,756	
Unknown (individuals not reporting ethnicity)	22,616	25,881	28	48,525	
Ethnic Category: Total of All Subjects*	62,403	92,810	31	155,244	*
Racial Categories					
American Indian/Alaska Native	871	1,652	0	2,523	
Asian	1,580	2,253	0	3,833	
Native Hawaiian or Other Pacific Islander	***	***	***	***	
Black or African American	1,364	3,905	0	5,269	
White	46,319	67,020	4	113,343	
More Than One Race					
Unknown or Not Reported	12,269	17,980	27	30,276	
Racial Categories: Total of All Subjects*	62,403	92,810	31	155,244	*

PART B. HISPANIC ENROLLMENT REPORT: Number of Hispanics or Latinos Enrolled to Date (Cumulative)

Racial Categories	Females	Males	Unknown or Not Reported	Total	
American Indian or Alaska Native	23	24	0	47	
Asian	12	46	0	58	
Native Hawaiian or Other Pacific Islander	***	***	***	***	
Black or African American	47	111	0	158	
White	850	2,940	0	3,790	
More Than One Race					
Unknown or Not Reported	823	3,087	0	3,910	
Racial Categories: Total of Hispanics or Latinos**	1,755	6,208	0	7,963	**

* These totals must agree.
** These totals must agree.
*** WTR uses a single combined category for Asian/Pacific Islander, so the breakdown is unknown. The combined numbers were entered on the lines for “Asian” and no numbers were entered on the line for “Native Hawaiian or Other Pacific Islander.”

Publications

1. Sears JM, Bowman SM, Hogg-Johnson S: [2014] Using injury severity to improve occupational injury trend estimates. American Journal of Industrial Medicine 57(8):928-939.

This manuscript addresses **Specific Aim 1**. We assessed whether implementing a severity threshold would improve occupational injury surveillance. 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. 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.

2. Sears JM, Bowman SM, Hogg-Johnson S, Shorter Z: [2014] Linkage and concordance of trauma registry and hospital discharge records: Lessons for occupational injury surveillance and research. Journal of Occupational and Environmental Medicine 56(8):878-885.

This manuscript addresses **Specific Aim 3**. Linked trauma registry and hospital discharge records were used to assess data field concordance and to assess the validity of using payer or E-codes to identify work-related injuries. There was substantial agreement between WTR and hospital discharge records for workers' compensation as primary payer. E-code based methods of identifying occupational injuries had high specificity (more than 99%) but low sensitivity (less than 14%). Payer was 76% sensitive and 98% specific. We found substantial agreement for data fields key to occupational injury surveillance and research. Nevertheless, many work-related injuries could not be identified using hospital discharge records.

3. Sears JM, Bowman SM, Hogg-Johnson S, Shorter Z: [2014] Occupational injury trends derived from trauma registry and hospital discharge records: Lessons for surveillance and research. Journal of Occupational and Environmental Medicine 56(10):1067-73.

This manuscript addresses **Specific Aim 2**. We compared occupational injury rates and trends estimated from the WTR with those derived from state hospital discharge data. We documented substantial similarity between occupational injury trends estimated using either WTR or hospital discharge data.

4. Sears JM, Bowman SM, Hogg-Johnson S: [2015] Disparities in occupational injury hospitalization rates in five states (2003-2009). American Journal of Industrial Medicine 58(5):528-540.

This manuscript addresses **Specific Aim 1**. Hospital discharge data from five states were used to calculate age-adjusted rates and trends for work-related injury hospitalizations. We found evidence of substantial multistate disparities in occupational injury-related hospitalizations. Latinos were significantly more likely to have a work-related traumatic injury hospitalization. The disparity for Latinos was greatest for machinery-related hospitalizations. Latinos were also more likely to have a fall-related hospitalization. African-Americans were more likely to have an occupational assault-related hospitalization, but less likely to have a fall-related hospitalization. An additional hypothesis, that the degree of disparity in injury burden for Latinos has increased over time, was borne out only in one of the five states.

5. Sears JM, Bowman SM, Rotert M, Hogg-Johnson S: [Online first: April 22, 2015] A new method to classify injury severity by diagnosis: Validation using workers' compensation and trauma registry data. Journal of Occupational Rehabilitation http://dx.doi.org/10.1007/s10926-015-9582-5

This manuscript addresses **Specific Aim 1**. This study assessed a severe injury indicator constructed from the list of severe traumatic injury diagnosis codes developed for the new Occupational Health Indicator #22, which was developed as a result of this grant. The severe injury indicator was a significant predictor of WTR inclusion, early hospitalization, compensated time loss, total permanent disability, and total medical costs. We concluded that severe traumatic injuries can be directly identified when diagnosis codes are available. This method provides a simple and transparent alternative to AIS-based injury severity estimation.

Inclusion of Women and Minorities

The distribution of subjects included in this study reflected the demographics of the underlying population. This project neither recruited nor excluded any sex/gender or racial/ethnic group. There were no subject selection criteria related to selection of sex/gender or racial/ethnic group members. All study procedures relied on secondary analyses of existing data and subjects were not contacted (a waiver of consent/authorization was obtained).

We have included two Inclusion Enrollment Reports, one for CHARS data and one for WTR data, because the two databases use incompatible race/ethnicity categories. Please note that WTR data include Native Hawaiian/Other Pacific Islander within the Asian category, and only a single race is reported. The numbers in the Inclusion Enrollment Reports are markedly lower than in the original Targeted/Planned Enrollment Table because it was unknown at that time exactly how many records would be excluded before data delivery due to our inclusion/exclusion criteria.

Inclusion of Children

Children under 16 years old were excluded from this study because this research was focused on work injuries and the number of employed children under 16 years of age is so small that meaningful statistical analyses could not be conducted. It is standard practice for employed population estimates to exclude children under 16. Children 16 years of age and over were included in this study, as they represent an important sector of the working population.

Materials Available for Other Investigators

N/A

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