Final Progress Report

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Use of the Washington State Trauma Registry for Occupational Injury Surveillance

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List of Terms and Abbreviations

ACS	American Community Survey
AIC	Akaike Information Criterion
AIS	Abbreviated Injury Scale
BLS	Bureau of Labor Statistics
CD	case definition
CFOI	Census of Fatal Occupational Injuries
CHARS	Comprehensive Hospital Abstract Reporting System
CI	confidence interval
DOA	Dead on arrival
DOH	Washington State Department of Health
DSHS	Washington Department of Social and Health Services
E-codes	ICD-9-CM external cause of injury codes
ED	emergency department
EMS	Emergency Medical Services
FACE	Fatality Assessment and Control Evaluation
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 applicable
NTDB	National Trauma Data Bank
OFM	Washington State Office of Financial Management
OIICS	Occupational Injury and Illness Classification System
OR	odds ratio
NISS	New Injury Severity Score
NS	not significant
SE	standard error
SHARP	L&I's Safety & Health Assessment & Research for Prevention program
SHR	subhazard ratio
TBI	traumatic brain injury
TL	time loss compensation
TPD	total permanent disability
WC	workers' compensation
WTR	Washington State Trauma Registry

Abstract

Project title: Use of the Washington State Trauma Registry for Occupational Injury Surveillance

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The goal of this project was to explore and document the Washington State Trauma Registry (WTR) as a potential resource for occupational injury surveillance and research. There were 125,625 deduplicated injury events reported to the WTR for 16+year-olds injured in Washington during 1998-2008, of which 9,185 (7.3%) were work-related. WTR records were linked to workers' compensation (WC) claims data maintained by the Washington State Department of Labor and Industries (L&I). The WTR work-related indicator exhibited 87% sensitivity and 97% specificity. Of WTR work-related injuries, 27% did not have L&I listed as an expected payer and 37% did not link to a compensable WC claim. Injured workers without a WC claim were more likely to be older, have no insurance, have been injured at home or in motor vehicle traffic, and less likely to have been injured at industrial locations or by machinery. The WTR captured about 25% of Washington's occupational fatalities. There were significant upward trends from 2003 through 2008 in age-adjusted rates of moderate and severe work-related traumatic injuries, but flat trends when minor injuries were included. We found not only a disparity in the burden of work-related traumatic injuries sustained by Latinos relative to non-Latinos, but also that the disparity increased over time. Abbreviated Injury Scale (AIS)-based injury severity measures (both those contained in WTR data and those we estimated from WC ICD-9-CM billing codes) were significant predictors of work disability and medical cost outcomes. Several findings suggested increasingly intensive efforts by trauma hospitals to identify potential payers. Among workers with L&I as a payer, workers who also had other insurance coverage had nearly twice the odds of having no WC claim. Latinos were more likely to have L&I as a payer (87% compared with 73% for non-Latinos) and less likely to have other insurance (14% compared with 31%), but were not more likely to have a linked WC claim after controlling for demographics, injury severity, and insurance. There are several important implications of this study: (1) linking injury details from WTR records with work disability and cost outcomes data from WC records enabled more comprehensive occupational injury surveillance and research; (2) AIS-based injury severity measures have rarely been used in occupational injury research but have many potential applications, including risk adjustment for program evaluation, intervention, or outcome studies and severity restriction for constructing comparison groups or case definitions; (3) additional mandatory WTR data fields should be considered, including work status (e.g., full-time or part-time traditional employment, self-employed, family business, temporary agency, contingent employment, casual/day labor, etc.), nativity, language, income, and educational level; (4) this study demonstrated the importance of considering differential access to other insurance coverage and adaptation by health care settings to financial pressures when assessing trends in occupational injury incidence and reporting, especially when using payer (WC) as a proxy for work-relatedness; (5) further research into potential cost-shifting from WC to other health insurance is indicated; and (6) the impact of severity restriction on observed injury trends is particularly provocative, with implications for surveillance methodology.

Section 1

Significant (Key) Findings

The goal of this project was to explore and document the Washington State Trauma Registry (WTR) as a previously underutilized data source for occupational injury surveillance and research. The primary hypothesis was that the WTR would be useful both as a stand-alone data source and as a source of data supplemental to the workers' compensation (WC) claims data maintained by the Washington State Department of Labor and Industries (L&I).

Sample and linkage to WC claims. There were a total of 125,625 deduplicated injury events reported to the WTR from 1998 through 2008 that met our inclusion criteria (injuries occurring in Washington State to people at least 16 years old). 9,185 WTR injury events (7.3%) were work-related according to the WTR. 6,673 WTR injury events were linked to compensable WC claims. 27% of WTR work-related injuries did not have L&I listed as a payer and 37% of WTR work-related injuries did not link to a compensable WC claim. Injured workers without a linked WC claim tended to be older and were more likely to have no insurance. They were more likely to have been injured at home or in a motor vehicle traffic incident, and less likely to have been injured at an industrial location or by machinery. Although nearly 99% of WC claims did not link to a WTR event, 30% of fatal claims and 5% of total permanent disability claims were linked. About a quarter of Washington's occupational fatalities were captured by the WTR.

WTR work-related field. Using linkage to an accepted compensable WC claim as the gold standard, the overall sensitivity of the work-related indicator was 87%, and the lower-bound specificity was 97%, varying significantly by injury location and external cause.

Injury trends. We found significant upward trends from 2003 through 2008 in age-adjusted rates of moderate and severe work-related traumatic injury reports, in contrast to approximately flat trends when minor work-related traumatic injury reports were also included.

Ethnicity. We found not only a disparity in the burden of work-related traumatic injuries sustained by Latinos relative to non-Latinos, but also that the disparity increased over time. There was a 5% mean annual increase in the odds that a comparable work-related traumatic injury was sustained by a Latino ($p=.007$), after controlling for Latino representation in the labor force. Falls in industrial locations were the strongest contributor to the increasing disparity.

Occupational Injury and Illness Classification System (OIICS). We described the accuracy and completeness of case classification and case-finding for various OIICS-based case definitions for traumatic brain injury (TBI), using clinically-identified TBI in WTR data as the gold standard. Though highly specific, all OIICS-based case definitions had low sensitivity, capturing less than a third of fatal or nonfatal work-related TBI. A high proportion of TBI was obscured within the OIICS categories for multiple traumatic injuries and/or multiple body parts.

Injury severity. Abbreviated Injury Scale (AIS)-based injury severity measures (both those contained in WTR data and those we estimated from the ICD-9-CM codes available in WC billing data) were significant predictors of work disability and medical cost outcomes.

Trends in payer. We observed no decrease over time in the percentage of this set of relatively severe traumatic injuries that were covered by WC, measured either by (1) L&I as an expected payer or (2) linkage to a WC claim. We found that work-related injury events reported to the WTR were increasingly likely over time to have L&I as a payer or to be uninsured. The percentage with other insurance listed as a payer did not measurably change, despite the state's decreasing trend in insurance coverage. This suggests that there may have been increasingly intensive efforts by trauma hospitals to identify potential payers.

Injury severity and payer. We observed no significant association between injury severity and

linkage to a WC claim in this set of relatively severe injuries. However, workers with more severe injuries were significantly more likely to have other insurance listed as a payer, alone or in addition to L&I. The mechanism is unknown, but could be related to hospitals being more highly motivated to identify all potential payers for more severe (more costly) injuries.

Ethnicity and payer. Latinos were more likely to have L&I listed as an expected payer (87% compared with 73% for non-Latinos), and less likely to have other insurance listed (14% compared with 31%). There was no significant difference in the odds of having a linked WC claim for Latinos compared with non-Latinos after controlling for age, sex, year of injury, ISS, and other insurance, and partially controlling for L&I coverage via sample restriction.

Other insurance coverage. Among workers with L&I listed as an expected payer, workers who also had other insurance coverage had nearly twice the odds of having no linked WC claim (OR: 1.89, 95% CI: 1.57, 2.26), with no significant interaction by ethnicity. This suggests the possibility of some degree of cost-shifting to other private/government insurance.

Translation of Findings

Although this study did not result in a product directly transferable to workplaces, one important goal was to provide WTR and L&I staff with information directly useful for improved occupational injury surveillance and research. We summarized pertinent findings and implications and provided separately tailored reports to WTR staff and L&I researchers in the Safety & Health Assessment & Research for Prevention (SHARP) program. SHARP is committed to using surveillance data for effective public health action, and serves as a scientific resource for the primary occupational health stakeholders Washington State, including employers, labor organizations, workers, health care providers, and occupational/public health professionals.

Outcomes/ Impact

There are several potential outcomes of this study: (1) We found that linking the rich injury detail contained in trauma registry records with the long-term work disability and cost outcomes data contained in WC records was feasible and enabled more comprehensive occupational injury surveillance and research, particularly disparities research. This study added to the previously limited knowledge base regarding the use of trauma registries, and may encourage further work along these lines. (2) Although commonly used in trauma research, AIS-based injury severity measures have rarely been used in occupational injury research. This study motivates the use of these measures for a variety of novel and important applications, including risk adjustment for program evaluation, intervention, or outcome studies, or severity restriction when constructing comparison groups or case definitions for surveillance. (3) Based on our findings, we have presented recommendations to WTR staff regarding the inclusion of additional work-related mandatory data fields, such as work status (e.g., full-time or part-time traditional employment, self-employed, family business, temporary agency, contingent employment, casual/day labor, etc.), nativity, language, income, and educational level, and we will be pursuing available avenues to encourage change in that regard. (4) This study demonstrated the importance of considering differential access to other insurance coverage and adaptation by health care settings to financial pressures when assessing trends in occupational injury incidence and reporting, especially when using payer (WC) as a proxy for work-relatedness. This study also reinforced the need for further research into potential cost-shifting from WC to other health insurance and the impact of health insurance coverage on the likelihood of a WC claim being filed. (5) We observed flat injury trends when minor injuries were included and increasing trends when minor injuries were excluded. The impact of severity restriction on observed injury trends is a particularly important area to understand, and there are implications for improving surveillance methodology. The findings of this study have motivated a new NIOSH-funded research project specifically on this topic, currently in progress.

Section 2

Scientific Report

Background

Despite a recent popular focus on occupational musculoskeletal injuries, acute work-related trauma remains a leading cause of death and disability among U.S. workers. 9,000 workers are treated daily in emergency departments, and approximately 200 of those are hospitalized.[1] Severe traumatic injury can lead to long-term pain and disability and is very costly for WC systems and society as a whole.[2] Though most states have an active state trauma registry, these registries remain an untapped resource for occupational injury research in many states. Trauma registry data has been used in Alaska and Illinois for occupational injury surveillance and in Illinois for research on ethnic disparities in traumatic occupational injury rates,[3-10] but had not been used in Washington State for such purposes prior to this project. The Washington State Trauma Registry (WTR) contains long-term reporting data as far back as 1993 (reporting is mandatory for designated acute trauma facilities). About 7% of the approximately 15,000 injuries per year captured by the WTR are identified as work-related, with falls accounting for about 1/3 of those injuries.[11] The WTR is well-positioned to capture several types of severe work-related traumatic injuries that are high priority areas for L&I and NIOSH, including work-related motor vehicle accidents, falls, traumatic head and brain injury, and workplace violence.

Occupational health services researchers have a high degree of interest in exploring new data sources for work-related injury surveillance, because of filters and barriers to complete work injury reporting that differentially affect various databases.[3-5,10,12-14] The use of trauma registry data may avoid some recognized reporting filters,[4] specifically whether a WC claim is filed or accepted for a particular injury or whether an employer recognizes and reports a particular injury as work-related. For example, researchers working with the Illinois Trauma Registry found no significant decline in occupational traumatic injuries between 1995 and 2003, in contrast with reports from national employer-reported surveillance data.[6]

In addition to exploring the WTR as a stand-alone data source for occupational injury surveillance, this study involved linking WTR data with L&I WC claims data. A search of the relevant research literature and consultation with L&I research staff did not turn up any prior example of linkage of trauma registry data and WC claims data. Such linkage provides several advantages over the use of either data source alone and creates the opportunity to address several understudied research questions. For example, minority subgroups of injured workers may face more barriers to WC claim filing, but little research is available regarding differential under-claiming or under-reporting by race/ethnicity.[15,16] Linking trauma registry data to WC data may prove useful in evaluating whether certain subpopulations are more likely to file or obtain coverage for a WC claim. This is not readily evaluated using either WC claims data alone (race/ethnicity data are often not available in WC databases) or other surveillance databases alone (work-relatedness may be reported, but whether or not a WC claim was filed or accepted may not be documented). Linking the two data sources also allows for tracking changes in the rate of under-filing/under-claiming for work-related trauma over time. There is some evidence that under-reporting of work-related injuries, particularly for less severe injuries, and cost-shifting from WC to other public or private health care coverage and/or workers themselves is significant and on the rise.[12,17-21] Finally, linking the two data sources has the potential to provide valuable information generally lacking from WC claims data for a subset of WC claims (those resulting from traumatic injuries recorded in the WTR). This additional data includes: (1) race/ethnicity, (2) several types of injury severity measures, (3) pre-existing conditions, and (4)

hospital procedures and charges for the injury-related admission (the latter is available for State Fund WC claims, but lacking for those covered by self-insured employers). These measures may be quite useful for case mix/severity adjustment for a variety of research purposes.

This study also provides important exploratory information for occupational health researchers anticipating a fully developed population-based national trauma registry. Although progress has been made, state trauma registries vary considerably in reporting requirements, inclusion criteria, data elements, and coding conventions.[22,23] The American College of Surgeons has made progress by developing the National Trauma Data Bank (NTDB) and has recently issued a new data dictionary that specifies that participants should collect occupation and occupational industry for all injuries flagged as work-related (not currently available in the WTR).[24] However, the NTDB is currently represented as a convenience sample rather than as population-based and does not include the patient identifiers necessary for linkage with WC data. This study provides information that should be of great interest to stakeholders contemplating the further development of a national population-based trauma database that could be linked to both state-based and cross-state WC data (such as that generated by private insurers and self-insured employers).

Specific Aims

The overall goal of this project was to explore and document the Washington State Trauma Registry (WTR) as a previously underutilized source of data for work-related injury surveillance and occupational health services research. The primary hypothesis was that the WTR would be useful for work-related injury research both as a stand-alone data source and as a source of data supplemental to the workers' compensation (WC) claims data maintained by the Washington State Department of Labor and Industries (L&I). Specifically, the WTR has previously unexplored potential to serve as a source of surveillance data to more fully capture the burden of severe occupational traumatic injury in Washington State, including the identification of populations at high risk and the identification of new or emerging injury patterns. In addition, it has the potential to contribute valuable information to L&I's ongoing research program that could assist with the planning, implementation and evaluation of programs related to occupational traumatic injury prevention. The WTR contains pertinent information either not present in L&I claims data or present only for a subset of claims, including: race/ethnicity, several types of injury severity measures, pre-existing conditions, and hospital procedures and charges for the injury-related admission. Finally, as an independent data source containing information on work-relatedness and payer, the WTR has the potential to contribute to assessments of under-reporting and differential WC claim filing by various subpopulations, as well as being a potential source of longitudinal data on cost-shifting for work-related injuries.

Specific Aim 1: *Describe work-related injuries captured by the WTR and explore and document the WTR as a resource for occupational injury surveillance/research.*

1a. Assess data quality, particularly the amount of missing data for key data elements and unresolved duplicate records.
1b. Summarize descriptive statistics related to work-related traumatic injuries captured by the WTR, including demographics, payer, injury descriptors, severity, and pre-existing conditions.

Specific Aim 2: *Explore and document the feasibility and utility of linking WTR data to Washington State WC claims data to enhance state-based occupational injury research.*

2a. Use deterministic and probabilistic linkage algorithms to link WTR injuries to Washington State WC claims. Compare linkage rates and resource requirements with simpler deterministic linkage methods.

2b. Describe concordance between WTR work-related injuries and Washington State WC claims.

- **i.** Describe the numbers of work-related injuries captured by the WTR alone, L&I claims data alone, and by both. Calculate the proportion of WTR work-related injuries having WC claims filed with L&I, and conversely the proportion of L&I claims represented in the WTR. Assess the sensitivity and false negative rate of the WTR work-related field.
- **ii.** Describe the types of injuries involving WC claims that are most completely represented in the WTR.
- **iii.** Describe whether concordance is better in particular geographic regions.

2c. Evaluate the association of WTR-based severity measures with the limited severity measures available in L&I claims data, and evaluate whether WTR-based severity measures add value over and above L&I-based data for control of confounding or predicting total compensated time loss.

2d. After conducting the above analyses, meet with L&I research staff to share findings and discuss whether and how L&I research might be enhanced by the addition of measures available in the WTR but not in L&I claims data (e.g., measures of baseline severity, pre-existing conditions, race/ethnicity).

Specific Aim 3: *Explore and document the extent of under-representation of work-related traumatic injuries in L&I claims data and the potential of the WTR to contribute to case ascertainment. Evaluate whether there are trends in under-representation over time, overall and by severity and race/ethnicity.*

3a. Describe the number and proportion of work-related traumatic injuries captured by the WTR that do not have an associated L&I WC claim.

3b. Evaluate whether under-representation varies by severity and/or race/ethnicity.

3c. Evaluate whether there are trends in under-representation rates over time.

Specific Aim 4: *Describe the distribution of payers and evaluate trends in payer coverage for work-related traumatic injuries captured by the WTR, overall and by severity and race/ethnicity.*

4a. Of all work-related trauma in the WTR, calculate the proportion covered by each payer category.

4b. Evaluate whether these proportions vary by severity and/or race/ethnicity.

4c. Evaluate whether these proportions change over time.

Methodology

Study Population and Data Sources

This study involved obtaining and linking data from two state government agencies: (1) the WTR, maintained by the Washington State Department of Health (DOH), and (2) WC claims data, maintained by the Washington State Department of Labor and Industries (L&I). All WTR traumatic injury reports and all WC claims were requested for the years 1998 through 2008, excluding injuries among those younger than 16 and those occurring outside Washington State.

The WTR contains reporting data for traumatic injuries meeting specific inclusion criteria from all state-designated acute trauma facilities (Levels I through V). The DOH designates trauma services as part of the comprehensive statewide emergency medical services and trauma care system. Mandatory reporting began in 1995, and trauma coverage gradually increased as the trauma system added new hospitals. The purposes of the registry as defined in the Washington Administrative Code are "to: (a) provide data for injury surveillance, analysis, and prevention programs; (b) monitor and evaluate the outcome of care of major trauma patients, in support of statewide and regional quality assurance and system evaluation activities; (c) assess compliance with state standards for trauma care; (d) provide information for resource planning, system design and management; and (e) provide a resource for research and education."[25] The WTR has not been utilized for injury surveillance because the state's Comprehensive Hospital Abstract Reporting System (CHARS) is more comprehensive for most surveillance purposes. However, the CHARS hospital discharge records do not contain specific information about whether the hospitalization was work-related (other than payer), limiting its utility for occupational injury research. The WTR also has limitations for surveillance of severe occupational injuries due 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. In addition, the WTR has included ethnicity data since its inception, while CHARS did not begin including ethnicity data until 2007.

The specific WTR inclusion criteria have undergone some refinements over time. For most of the years of this study, reports were mandatory for adult patients who were discharged with ICD diagnosis codes of 800-904 or 910-959 (injuries), 994.1 (drowning), 994.7 (asphyxiation), or 994.8 (electrocution) AND met at least one of the following criteria: trauma resuscitation team activation, dead on arrival or death during hospital stay, interfacility transfer by Emergency Medical Services (EMS) or ambulance, or inpatient admission of at least 48 hours. (The criteria for patients under 15 years old are somewhat different but not relevant to this study.)

In a nationwide survey conducted in 2004 by Mann, et al., the WTR trauma manager estimated that the WTR captured about 85% of trauma victims with injuries satisfying registry inclusion criteria.[22] However, the WTR does not capture data for the many occupational injuries that do not meet inclusion criteria.[11] In addition, occupational fatalities can occur in any setting and only those occurring after contact with the EMS and trauma system are reported to the WTR.[5]

Washington State has a single payer WC system (the State Fund) that covers approximately 70% of workers specified by the Industrial Insurance Act.[26] 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 (which account for the remaining 30%). Health care providers are required to file an accident report within 5 days of identifying a work-related injury, initiating the claim (claims can also be filed by the worker or the employer). Compensable State Fund and self-insured WC claims were obtained from L&I, excluding injuries among workers younger than 16 and injuries occurring outside Washington State. (Compensable WC claims include claims for fatalities, total permanent disability, and those involving compensation for work missed due to the injury.) The study excluded WC claims with special confidentiality-related restrictions and medical aid-only claims. Medical aid-only claims cover medical treatment but do not involve time-loss payments because the injury did not cause any missed work days after the initial three-day post-injury waiting period. A preliminary assessment found that very few medical aid-only claims linked to the relatively severe traumatic injuries reported to the WTR; hence those claims were not released by L&I as initially planned. This project was approved by the Washington State Institutional Review Board.

Data Quality

The WTR has conducted periodic validity studies assessing factors such as coding accuracy. The software used by the hospitals to collect and submit data to the registry contains logic checks and error checks that facilitate data quality and completeness.

We conducted an assessment of the amount of missing data in key data fields for each year from 1998 through 2008. The WTR has made adjustments to mandatory reporting fields over time and worked to improve reporting, which is reflected in the amounts of and trends in missing data. First and last name, date of birth, gender, injury date, and emergency department (ED) arrival date were each missing in less than 1% of records. Social Security number was missing in 8% of records. Zip code of injury was present in only 20% of records, and county of injury was not required and almost always missing prior to 2002, but missing only for 3% of records from 2006 through 2008. The work-related field, of key importance to this project, was missing for 2.5% of records overall, decreasing over time from 5% to <1%. Payer was missing for 4%, decreasing over time from 8% to <1%. Race (19%) and ethnicity (35%) were more frequently missing, with little decrease over time. Injury Severity Score (ISS), injury mechanism, and primary ICD-9-CM diagnosis and E-code were missing for less than 1% of records. Injury place was missing for only 3%, however another 8% had an "unspecified" place of injury. Hospital charges were missing for 25% of records and information on pre-existing conditions for 17% (the latter decreased markedly over time, from 56% to 5%).

Data Linkage and Deduplication of Injury Reports

Records were linked and deduplicated at the injury event level using The Link King, a public domain software program developed in Washington State for deterministic and probabilistic linkage of administrative records.[27] The Link King pulls together a variety of complex deterministic algorithms to increase the likelihood of finding matches across databases, including phonetic name matching, approximate string matching, and nickname matching.

A 2-stage procedure was used so that the necessary identifiers were in hand only for the initial linking procedures (full name, date of birth, gender, last 4 digits of the Social Security number, and county and zip code where the injury occurred), and the bulk of the data was obtained only after linkage was complete and identifiers were stripped. In addition to confidentiality protection, this procedure isolated the work-related indicator, payer, and E-codes from the linkage procedure, so that sensitivity estimates could not be consciously or unconsciously affected by the PI during linkage procedures (e.g., by going to more lengths to link injuries identified as work-related in the WTR).

There were 3 main steps involved in linking the two databases: (1) unique individuals were identified within each database and across the two databases, (2) multiple WTR injury reports for the same injury event were grouped together within unique individuals, and (3) specific injury events were linked with associated WC claims within unique individuals. In step (2), WTR reports were grouped together if they were for the same individual AND two reports (a) had the same injury date, or (b) had the same ED arrival date, or (c) the injury date of one matched or was one day prior to the ED arrival date of another, or (d) were from different hospitals and the discharge date of one matched or was one day prior to the ED arrival date of another). Although some of these grouped reports could have originated from separate injuries occurring very close in time, injury descriptors were almost always the same or very similar and usually there was an ED disposition indicating interfacility transfer. All non-exact matches were reviewed by the PI for

plausibility. 16% of injury events had multiple records (up to 4), most commonly because several hospitals reported the same injury due to transfers within the continuum of care.

Denominators

For analyses of injury trends from 2003-2008, data from the American Community Survey (ACS) were used for Washington State employed population denominators and employed subpopulations broken out by gender, age, race, and ethnicity. The ACS is a national annual representative survey administered by the U.S. Census Bureau. Survey responses (mail, phone, and/or in-person) are required by law. Coverage rates were at least 95% and response rates ranged from 93.0% to 97.6% for the years pertinent to this study.[28]

For analyses of trends by ethnicity from 1998-2008, annual Washington State civilian labor force estimates broken out by gender, age, and ethnicity were provided by the Washington State Office of Financial Management (OFM). The OFM estimates combine state-level demographically detailed population counts with Bureau of Labor Statistics (BLS) data for the civilian non-institutional labor force, which is composed of individuals age 16 or older who were employed (either part-time or full-time) or who were actively seeking employment.

Data Fields and Measures

In general, where data varied by report within an injury event, we assumed that the most comprehensive trauma care hospital (i.e., highest trauma designation level) provided the most reliable report, per the advice of WTR staff. Missing data was filled in using other reports when feasible. However, for some variables, data from all reports for an injury event were consolidated. For example, an injury was considered work-related if any of the related reports were indicated as being work-related. Detailed information about each WTR field is available in the online WTR data dictionary.[29]

Hospital charges were summed across hospitals for each injury event. Total length of stay (LOS) was constructed using WTR records by subtracting the first recorded ED arrival date from the last recorded hospital discharge date after stringing together related hospitalizations for each distinct injury event. To assign calendar years, we used the ED arrival year of the first report for each distinct injury event (for the fewer than 1% of cases where injury year and ED arrival year didn't match exactly, injury dates were either missing, were within a few days of the ED arrival date, or appeared to be data entry errors). Early hospitalization was defined as the presence of any inpatient hospital bill for a date of service within 30 days of injury. Fatalities were defined as workers who died prior to or during the initial hospitalization according to WTR data, or whose WC claim was classified as a fatality.

Work-Related Measures

The WTR work-related indicator is minimally defined. The registry software (now used by all participating hospitals) asks "Work Related? Yes No." The WTR data dictionary that guides the hospital-based trauma registrars in reporting registry data states only "Work related injury as documented in the patient's medical record." According to Mary Rotert, RN, MS, CAISS, Trauma Clinical Consultant at the Washington State Department of Health, there are several ways this information may be gathered: (1) the patient (if conscious) is typically asked about

work-relatedness during registration (in order to initiate a WC claim when appropriate), (2) work-relatedness may be recorded on the hospital face sheet of admitted patients, (3) there may be information about work-relatedness contained in the clinician or nursing notes or in the history section of the ED admitting form, and (4) the EMS records may indicate that the injury was work-related. There is no specified standard that must be met before recording the injury as being work-related either in the medical record or for WTR reporting.

The purpose of ICD-9-CM E-codes is to capture the circumstances and external cause of an injury. The WTR data contain two E-code fields as well as a place of injury field that is based on E-codes and other available information but follows the same coding structure as that for the E-code E849.X. Alamgir et al presented a list of E-codes that could be used to identify a work-related injury 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).[3] We created an E-code based work-relatedness indicator following the same scheme. (Note: the range of E-codes for water transport presented in Table 1 of the Alamgir study[3] contained typographical errors and should be E830-838.)

Linkage to an accepted compensable WC claim also presumptively indicated work-relatedness (regardless of work-related status in the WTR).

Payer

Payer was based on the two expected payer fields available in the WTR. We created three overlapping payer categories based on the presence of a particular payer in either expected payer field of any related report for each reported injury: (1) L&I (including State Fund and self-insured coverage), (2) other insurance (e.g. government, private), and (3) no insurance (e.g., self-pay, charity). These were combined to create 5 mutually exclusive categories for some analyses: (1) L&I only, (2) L&I and other insurance, (3) other insurance only, (4) no insurance, and (5) missing payer information. Federal WC coverage would be captured in the other insurance category rather than the L&I category. The presence of L&I in either payer field would indicate that L&I was identified as a potential payer, but not necessarily that a WC claim was actually filed or accepted. There was an additional and perhaps unique complication in that L&I also manages the Washington State Crime Victims Compensation Program. The trauma registrars are directed to indicate L&I as payer for WC claims (both State Fund and self-insured) and crime victim claims. Thus L&I in either payer field does not necessarily signify that an injury was work-related.

Ethnicity

In the software used by reporting hospitals, ethnicity was a required element (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.” Missing data was filled in when feasible using ethnicity information contained in related reports for the same injury, prioritized by trauma designation level. We used Latino as a synonym for Hispanic origin.

After deduplication and consolidation, most key fields contained few missing data. In contrast, the ethnicity field was missing 32.1% of the time overall, and non-monotonically decreased from

a high of 35.9% in 1998 to a low of 27.6% in 2008.This implied that ethnicity-based injury rates would be underestimated, and suggested the potential for upward bias in trends based on ethnicity. Therefore, in addition to estimating rates by ethnicity, we assessed trends in the odds that a comparable reported injury was sustained by a Latino versus a non-Latino, adjusted for representation of Latinos in the relevant underlying labor force (stratified by calendar year, age, and gender). Although less informative than rates in terms of absolute burden of injuries, this approach allowed us to sidestep challenges inherent to relying on rates in the face of substantial and changing amounts of missing data.

Due to additional concerns about the high proportion of records with ethnicity recorded as "Unknown" at some hospitals, we created two samples for use in side-by-side analyses. The primary sample included all reports for which ethnicity was known, a total of 84,587 injuries (7,046 work-related injuries). Although this excluded 32.1% of the 125,625 total reported injuries (and 23.3% of the 9,185 work-related injuries), it retained the advantage of being a statewide sample with at least some representation by all 82 reporting hospitals. The second sample included only injuries which were treated by one of the 5 hospitals at which ethnicity was recorded as unknown for less than 5% of reports in every calendar year. Ethnicity was unknown for only 0.52% of this sample (0.47% of work-related injuries), and there was no apparent trend over time in missing data. We treated this as a confirmatory sample, to assess whether large amounts of missing data or trends in missing data may have substantially biased our findings. This sample contained 46,330 injuries (4,634 work-related injuries). WTR data did not provide adequate residential data or other information that would allow for imputation of ethnicity.

Traumatic Brain Injury (TBI)

TBI was defined using the Centers for Disease Control and Prevention (CDC) case definition: the presence of any ICD-9-CM code of 800.0-801.9, 803.0-804.9, 850.0-854.1, 950.1-950.3, or 959.01 in any of the 27 WTR diagnosis fields.[30,31]

Isolated TBI was defined as TBI that did not have any maximum Abbreviated Injury Scale (AIS) score greater than 1 (no more than minor injury) in body regions other than the head/neck, as well as no indication of additional moderate extracranial injury in the head/neck region (e.g., facial fractures, cervical spine injuries). TBI with other trauma was defined as TBI that had at least one maximum AIS score greater than 1 in a body region other than the head/neck or an ICD-9-CM code in the head/neck region indicating at least moderate extracranial injury.

Amputations

We classified amputations as the presence of any ICD-9-CM code of 885-887 or 895-897.

Cause of Injury

Cause of injury was based on the ICD-9-CM external cause of injury codes (E-codes) from WTR records and categorized according to CDC recommendations (several categories with very few injuries were moved into "other specified").[32] For some analyses, we used a modified classification scheme in order to facilitate comparison with previous related work in Illinois (refer to citation for details of their categorization scheme).[6]

Injury Severity

We focused on three recognized injury severity scores: (1) Injury Severity Score (ISS), which has been well-validated for the prediction of mortality[33] and remains the most common measure of injury severity used by trauma systems and in trauma research, (2) New Injury Severity Score (NISS), which has been found more predictive of injury mortality, particularly for penetrating injuries,[34,35] and (3) the overall maximum AIS (maxAIS), which performs as well as the ISS in at least some circumstances.[36,37] AIS ranges from 1 (minor) to 6 (nonsurvivable). ISS is the sum of squares of the highest AIS scores from up to three different body regions. NISS is the sum of squares of the three highest AIS scores, regardless of body region. Both ISS and NISS have a range of 1 to 75, with 75 assigned whenever maxAIS is 6.

Severity scores that were generated via expert assessment by trauma surgeons, review of medical records by trauma registrars, and/or estimated from ICD-9-CM codes by trauma registry software were contained in the WTR data.[22] Two software packages that estimate injury severity scores directly from ICD-9-CM codes have been used for injury research using hospital discharge data: (1) ICDMAP-90 software developed by and available from the Johns Hopkins Bloomberg School of Public Health,[38] and (2) Stata's user-written -icdpic- suite of programs, developed using National Trauma Data Bank (NTDB) data to assign approximate injury severity scores by classifying injuries into general severity and body region categories.[39] ICDMAP-90 is not current to the most recent ICD-9-CM and AIS changes and does not run on newer computers. -icdpic- is freely available and easily run by Stata users. -icdpic-based injury severity scores are now included in some ED discharge files released by the Healthcare Cost and Utilization Project (HCUP). For this project, severity scores were also estimated from the ICD-9-CM diagnosis codes available in the WTR and WC billing data using ICDMAP-90 and -icdpic-. We estimated severity scores for work-related injury events that involved at least one ICD-9-CM diagnostic code for a traumatic injury as specified by the NTDB (800-904.9, 910-929.9, 950-957.9, 959-959.9).[40] Isolated burns were excluded from these analyses because -icdpic- does not score burns. AIS-based injury severity scores do not reliably classify burns due to the importance of inhalation injuries, which are not scored by the AIS system.

ISS and NISS are technically non-continuous; a jump from an ISS of 1 to 2 means something quite different than a jump from 24 to 25.[41-43] Copes et al.[41] recommended categorizing ISS into 7 categories (1-8, 9-15, 16-24, 25-40, 41-49, 50-69, and 75) based on the specific AIS combinations that each category might contain. We categorized ISS following similar logic, except that we also took into account the very different distribution of ISS for WC claims compared with trauma registries (the setting in which ISS has been more commonly used). Due to large numbers of minor injuries and very small numbers of the most severe injuries (in part due to this study's focus on nonfatal injuries), we added an additional category of 1-3 and collapsed the highest four categories into a single category. The new 1-3 category was based on a similar theoretical underpinning; it can contain no injury with AIS above 1. This resulted in 5 categories (1-3, 4-8, 9-15, 16-24, and 25-75). These categories were collapsed further for various analyses based on the particular distribution of ISS and to ensure an adequate number of cases per category. For many analyses, we used the standard scheme of minor (1-8), moderate (9-15), and major (16-75).

Occupational Injury and Illness Classification System (OIICS)

We used the OIICS, developed by the Bureau of Labor Statistics (BLS), to identify the primary occupational injury and to identify denominators for the purpose of describing the feasibility of

injury severity scoring**.** L&I uses the 2007 version of the OIICS to identify and record injury/illness characteristics.[44] OIICS codes were available for essentially all State Fund and self-insured claims. For WC claims data, we used OIICS to identify a set of primary injuries that we would expect ICDMAP-90 and/or -icdpic- to be able to score given adequate ICD-9-CM codes using the following criteria for the OIICS nature of injury code: (1) the first digit was 0 (traumatic injuries and disorders), (2) the first two digits were not 05 (burns), (3) the first two digits were not 07 (effects of environmental conditions), and (4) the first three digits were not 091 (asphyxiation), 092 (drowning), 093 (electrocution), 095 (other poisonings and toxic effects), or 096 (traumatic injury complications).

Outcome 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. It should be noted that the end of time loss compensation, though a commonly-used proxy, has been found to underestimate the actual amount of time lost from work.[45] 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.

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 for inflation to December 2008 equivalents using the Consumer Price Index, based on month and year of injury. Data for the month and year that costs were actually incurred were unavailable. Paid-to-date costs accumulated over time, but were highly front-loaded, with more than 90% of medical costs occurring in the first month after injury for 92% of the claims (as well as for 80% of the claims with at least three years of time loss compensation). We conducted the analyses with and without this adjustment, and there was little practical difference. Self-insured claims were excluded from cost analyses because they lack detailed cost information.

Data Analysis

Analyses were performed using Stata/SE 11.2 for Windows (StataCorp LP, College Station, TX). Pearson's Chi^2 test of independence and the *t* test (with no assumption of equal variance) were used to test group differences. The Stata command -nptrend-, which performs the nonparametric test for trend across ordered groups developed by Cuzick,[46] was used to test payer trends. The Stata user-written program -diagt- was used to calculate sensitivity and related classification statistics.[47] The Stata user-written program -venndiag- was used to describe overlaps and discordancies between the three work-related indicators (the WTR field, E-codes, and payer).[48] Age adjustment was conducted using the Stata user-written program -distrate- to implement direct standardization with gamma confidence intervals (CI) [49] based on year 2000 U.S. standard working population weights.[50] Incidence rate ratios (IRR) and annual trends in injury rates were estimated using Poisson regression models.[51] Analytic details specific to particular analyses are reported with the related results.

Results and Discussion

Results are organized by specific aim. Every specific aim was fully addressed over the course of this exploratory project.

Specific Aim 1: ***Describe work-related injuries captured by the WTR and explore and document the WTR as a resource for occupational injury surveillance/research.***

1a. Assess data quality, particularly the amount of missing data for key data elements and unresolved duplicate records.

Data quality and missing data are described in the Methodology/Data Quality section above.

1b. Summarize descriptive statistics related to work-related traumatic injuries captured by the WTR, including demographics, payer, injury descriptors, severity, and pre-existing conditions.

For the 11 years studied, the WTR contained a total of 145,891 reports for 125,625 unduplicated injury events. There were 82 distinct reporting hospitals during that time, though not all were reporting for the entire time period. **Table 1** presents the number and average severity of traumatic injuries reported to the WTR for each year from 1998 through 2008, broken out by work-related versus other injuries. In 2000, and again in 2002, there were changes to the WTR inclusion criteria that may have affected the number and severity of traumatic injury reports. Therefore, the annual figures in **Table 1** should not be interpreted as a smooth series. On average, injury severity was slightly lower for work-related injuries compared with other injuries (mean ISS of 10.2 versus 10.9; P<.001). Mean length of stay for reported work-related injuries was 6.4 days compared with 6.1 days for other injuries (P=.01). These are small differences, and a number of factors likely contributed to the longer average length of stay for work-related injuries despite the lower average ISS, including demographics, payer, pre-existing conditions, and differential survival. Mean unadjusted hospital charges were $32,850 for work-related injuries compared with $31,571 for other injuries (difference not significant).

TABLE 1. Number and severity of traumatic injuries* reported to the WTR by year, 1998-2008

Year	Reporting Hospitals	Work-Related Injuries			Other Injuries			All Injuries	
	N	N	%	Mean ISS†	N	%	Mean ISS	N	Mean ISS
1998	75	698	8.8	8.9	7,202	91.2	10.7	7,900	10.5
1999	75	770	9.6	8.8	7,270	90.4	10.6	8,040	10.4
2000	79	823	8.3	8.9	9,044	91.7	10.1	9,867	10.0
2001	78	813	7.3	9.3	10,310	92.7	9.9	11,123	9.8
2002	79	838	7.6	9.2	10,161	92.4	9.9	10,999	9.9
2003	80	819	7.2	9.1	10,631	92.9	10.0	11,450	10.0
2004	81	815	6.7	9.2	11,427	93.3	10.2	12,242	10.1
2005	81	818	6.5	11.4	11,865	93.6	11.7	12,683	11.6
2006	81	932	6.8	12.5	12,797	93.2	12.0	13,729	12.1
2007	81	995	7.3	11.8	12,719	92.7	11.8	13,714	11.8
2008	80	864	6.2	11.4	13,014	93.8	11.7	13,878	11.7
All years	82	9,185	7.3	10.2	116,440	92.7	10.9	125,625	10.8

*Unduplicated injury events.
†Injury Severity Score scoring range: 1 to 75.

Men accounted for 88% of work-related injury reports, and injury characteristics varied by gender. **Table 2** presents a summary of demographic and injury characteristics, broken out by gender, for the 7.3% of WTR injuries that were work-related (N=9,185) for all 11 years combined.

TABLE 2. Work-related injuries reported to the WTR, 1998-2008 (N=9,185*)

Characteristic	Total		Men		Women	
	N	%	N	%	N	%
Gender						
Male	8,086	88.0	n/a	n/a	n/a	n/a
Female	1,098	12.0	n/a	n/a	n/a	n/a
Age						
16-24	1,351	14.7	1,223	15.1	128	11.7
25-34	2,002	21.8	1,851	22.9	151	13.8
35-44	2,221	24.2	1,986	24.6	234	21.3
45-54	2,064	22.5	1,776	22.0	288	26.2
55-64	1,125	12.3	943	11.7	182	16.6
65 and older	422	4.6	307	3.8	115	10.5
Race/ethnicity						
White	6,078	66.2	5,375	66.5	703	64.0
Latino/Hispanic (any race)	1,253	13.6	1,143	14.1	110	10.0
Black/African-American	194	2.1	168	2.1	26	2.4
Asian/Pacific Islander	221	2.4	184	2.3	37	3.4
Native American	65	0.7	55	0.7	10	0.9
Other	116	1.3	102	1.3	14	1.3
Unknown	1,258	13.7	1,059	13.1	198	18.0
Payer (categories not mutually exclusive)						
Labor & Industries	6,665	72.6	5,930	73.3	734	66.9
Medicare	278	3.0	207	2.6	71	6.5
Medicaid/DSHS/Healthy Options	355	3.9	305	3.8	50	4.6
Other insurance (government/private)	2,073	22.6	1,737	21.5	336	30.6
None (self-pay, charity)	1,148	12.5	1,012	12.5	136	12.4
No insurance information	281	3.1	252	3.1	29	2.6
Pre-existing conditions (selected)						
Previous trauma	452	5.8	402	5.9	50	5.4
Hypertension	919	11.9	757	11.1	162	17.4
Cardiac	362	4.7	291	4.3	71	7.6
Diabetes	388	5.0	325	4.8	63	6.8
Respiratory	336	4.3	267	3.9	69	7.4
Psychiatric	194	2.5	143	2.1	51	5.5
Drug abuse	187	2.4	177	2.6	10	1.1
Alcohol abuse	209	2.7	198	2.9	11	1.2
Tobacco use	1,299	16.8	1,203	17.7	96	10.3

Characteristic	Total		Men		Women	
	N	%	N	%	N	%
Injury Severity Score						
Minor (1-8)	4,133	45.2	3,578	44.5	554	50.6
Moderate (9-15)	3,195	35.0	2,791	34.7	404	36.9
Major (16-75)	1,814	19.8	1,676	20.8	138	12.6
Injury involved an amputation	587	6.4	531	6.6	56	5.1
Traumatic brain injury	1,910	20.8	1,718	21.3	192	17.5
Fatality (DOA or in-hospital)	247	2.7	236	2.9	11	1.0
External cause of injury						
Falls	3,507	38.2	2,978	36.8	529	48.2
Machinery	1,225	13.3	1,113	13.8	112	10.2
Motor vehicle traffic	835	9.1	683	8.5	152	13.8
Cutting/piercing objects	444	4.8	419	5.2	25	2.3
Struck by object	1,132	12.3	1,080	13.4	51	4.6
Caught between objects	382	4.2	361	4.5	21	1.9
Electrocution	143	1.6	137	1.7	6	0.6
Corrosive material/steam	286	3.1	241	3.0	45	4.1
Homicide/assault	147	1.6	117	1.5	30	2.7
Overexertion/movement-related	68	0.7	46	0.6	22	2.0
Fire/flames	182	2.0	173	2.1	9	0.8
Explosive materials	52	0.6	48	0.6	4	0.4
Animal bites	68	0.7	49	0.6	19	1.7
Other specified	707	7.7	636	7.9	71	6.5
Missing/Unspecified	7	0.1	5	0.1	2	0.2
Place of injury						
Home	524	5.7	418	5.2	106	9.7
Farm	456	5.0	387	4.8	69	6.3
Mine/quarry	27	0.3	23	0.3	4	0.4
Industrial	5,040	54.9	4,617	57.1	423	38.5
Sports/recreation	153	1.7	129	1.6	24	2.2
Street/highway	883	9.6	723	8.9	160	14.6
Public building	361	3.9	232	2.9	129	11.8
Residential institution	101	1.1	68	0.8	33	3.0
Other specified	904	9.8	809	10.0	95	8.7
Missing/Unspecified	736	8.0	680	8.4	55	5.0

*Categories for some characteristics do not sum to 9,185 due to missing data.

We assessed trends in occupational injuries reported to the WTR. During the timeframe of this study, there were two changes to the WTR inclusion criteria that may have 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 and the criteria related to inpatient death and trauma team activation were added. As of January 31, 2002, qualifying facility transfers were

limited to those involving EMS or ambulance. Therefore, years prior to 2003 were excluded from trend assessments.

Significant upward trends in unadjusted moderate and major traumatic injury reports were observed for all gender, ethnicity, and age categories, with the exception of age-specific rates for ages 16-24, for the timeframe from 2003 through 2008 (data not presented). After age-adjusting and controlling for changes in the underlying employed population, upward trends were more consistent between subgroups, with most ranging from a 4% to 9% mean annual increase (**Table 3**). Upward trends remained statistically significant in most subgroups, with the exception of several age categories. The 14.8% mean annual increase in injury reports for Latinos was the largest upward trend observed for any subgroup.

TABLE 3. Trends in moderate and major traumatic injury reports* by demographic characteristics, adjusted for changes in employed population (crude, age-adjusted and age-specific incidence rates per 100,000 workers†)

Characteristic	N	2003 (CI)	2004 (CI)	2005 (CI)	2006 (CI)	2007 (CI)	2008 (CI)	Mean annual % change	P
Overall, crude‡	3,093	14.6 (13.3-16.1)	14.2 (12.8-15.6)	16.7 (15.2-18.2)	19.5 (18.0-21.1)	19.8 (18.3-21.4)	17.2 (15.8-18.7)	+5.5	<.001
Age-adjusted§									
Overall	3,093	16.5 (15.1-18.1)	15.7 (14.2-17.2)	19.3 (17.7-20.9)	22.6 (20.9-24.3)	22.5 (20.9-24.2)	19.0 (17.5-20.5)	+5.3	<.001
Gender									
Men	2,745	25.5 (23.0-28.2)	24.9 (22.5-27.5)	28.8 (26.2-31.5)	34.5 (31.7-37.4)	34.3 (31.5-37.2)	29.8 (27.3-32.5)	+5.4	<.001
Women	348	6.6 (5.3-8.1)	4.6 (3.6-6.0)	7.9 (6.5-9.5)	8.6 (7.2-10.3)	8.8 (7.4-10.5)	6.6 (5.4-8.0)	+5.0	.04
Ethnicityǁ									
Latino	490	28.2 (21.4-36.5)	22.8 (16.9-30.0)	29.0 (22.5-36.9)	38.8 (31.4-47.5)	46.6 (38.6-55.7)	45.5 (37.8-54.2)	+14.8	<.001
Non-Latino	2,097	10.8 (9.6-12.2)	11.1 (9.9-12.5)	12.9 (11.6-14.3)	14.9 (13.5-16.4)	14.5 (13.2-16.0)	13.1 (11.9-14.5)	+5.3	<.001
Age-specific									
16-24	418	14.0 (10.6-18.3)	16.0 (12.3-20.4)	16.0 (12.4-20.3)	21.0 (16.8-25.9)	19.1 (15.1-23.8)	16.1 (12.5-20.4)	+4.1	.16
25-34	611	10.9 (8.5-13.9)	13.8 (11.0-17.1)	16.3 (13.3-19.7)	18.3 (15.2-21.9)	16.7 (13.8-20.1)	17.9 (14.9-21.3)	+8.6	.001
35-44	679	14.9 (12.2-18.0)	10.7 (8.5-13.4)	16.7 (13.8-19.9)	17.4 (14.5-20.7)	20.0 (16.9-23.6)	13.7 (11.1-16.6)	+4.2	.07
45-54	771	15.1 (12.3-18.2)	15.6 (12.8-18.8)	15.5 (12.7-18.6)	20.5 (17.4-24.0)	20.0 (17.0-23.4)	17.6 (14.8-20.8)	+5.1	.02
55-64	432	17.8 (13.6-22.8)	14.4 (10.8-18.8)	16.2 (12.5-20.7)	17.2 (13.5-21.6)	19.9 (16.0-24.5)	18.6 (15.0-22.9)	+3.8	.19
65 and older	182	28.4 (17.6-43.3)	24.6 (15.2-37.6)	35.5 (24.0-50.7)	41.5 (29.2-57.2)	40.0 (28.4-54.7)	31.8 (22.0-44.5)	+5.5	.22

CI, confidence interval.
*Restricted to injuries with Injury Severity Score≥9 to limit intra- and inter-facility reporting variation.
†Denominators based on American Community Survey estimates of employed population/subpopulations.
‡Crude estimates include 95% Poisson exact confidence intervals.
§Age-adjusted using year 2000 U.S. standard working population; 95% gamma confidence intervals.
ǁCounts too low to meaningfully test age-adjusted trends for other categories.

We also assessed trends by external cause of injury. We observed significant upward trends in unadjusted traumatic injury reports for falls, machinery, cutting/piercing objects, and corrosive material/steam (data not presented). There was no evidence of significant trends for motor vehicle traffic, struck by object, caught between object, or homicide/assault. A similar picture remained after age-adjusting and controlling for changes in the underlying employed population, except that the apparent upward trend in cutting/piercing objects was no longer statistically significant (**Table 4**).

Trends in reported moderate and major traumatic injuries are presented as rates based on annual ACS employed population denominators. We present rates because, in so doing, we can adjust for age and for changes in the employed population over time, and to allow for comparison with related work in other states. These rates should not be interpreted as absolute, since not all work-related moderate and major trauma is treated at designated trauma facilities, some injuries occurring in Washington may be treated in other states, and many severe work-related injuries will not meet the WTR inclusion criteria. In addition, capture of severe injuries may exhibit regional variation related to whether the transporting EMS is permitted to diagnose a death or is required to route to a hospital for that purpose. Therefore, the rates presented in **Tables 3 and 4** should be interpreted with caution. They do not represent the absolute incidence of any category of work-related injuries.

TABLE 4. Trends in moderate and major traumatic injury reports* by most common external causes, adjusted for changes in employed population (crude incidence rates per 100,000 workers†)

External Cause of Injury‡	N	2003 (SE§)	2004 (SE)	2005 (SE)	2006 (SE)	2007 (SE)	2008 (SE)	Mean annual % change	P
Falls	1,412	7.14 (0.50)	6.13 (0.46)	7.07 (0.49)	8.43 (0.52)	9.02 (0.54)	8.73 (0.52)	+6.8	<.001
Machinery	314	1.16 (0.20)	1.33 (0.22)	1.78 (0.25)	1.98 (0.25)	2.36 (0.27)	1.71 (0.23)	+10.2	.004
Motor vehicle traffic	309	1.51 (0.23)	1.86 (0.26)	1.62 (0.23)	1.95 (0.25)	1.82 (0.24)	1.49 (0.22)	+0.01	>.99
Cutting/piercing objects	61	0.25 (0.09)	0.11 (0.06)	0.40 (0.12)	0.49 (0.13)	0.32 (0.10)	0.43 (0.12)	+15.2	.07
Struck by object	388	1.65 (0.24)	2.03 (0.27)	2.59 (0.30)	2.53 (0.29)	2.33 (0.27)	1.71 (0.23)	+1.1	.71
Caught between objects	143	0.84 (0.17)	0.98 (0.19)	0.77 (0.16)	0.81 (0.16)	0.73 (0.15)	0.62 (0.14)	-6.4	.17
Corrosive material/steam	54	0.18 (0.08)	0.11 (0.06)	0.17 (0.08)	0.49 (0.13)	0.45 (0.12)	0.37 (0.11)	+25.9	.006
Homicide/assault	64	0.39 (0.12)	0.28 (0.10)	0.30 (0.10)	0.68 (0.15)	0.19 (0.08)	0.28 (0.09)	-3.7	.61

SE, standard error.
*Restricted to injuries with Injury Severity Score≥9 to limit intra- and inter-facility reporting variation.
†Denominators based on American Community Survey estimates of employed population.
‡External cause of injury based on ICD-9-CM codes; table limited to causes resulting in 50+ injuries.
§Standard errors assume Poisson distribution.

We assessed trends for two specific injury types, amputations and traumatic brain injuries (TBI), controlling for changes in the underlying employed population. There was a significant upward trend observed for both, with a 21.3% mean annual increase for amputations (P<.001; 95% CI: +9.8%, +34.0%), and a 7.4% mean annual increase for TBI (P<.001; 95% CI: +3.5%, +11.4%).

For the years 2003 through 2008 combined, the incidence of work-related traumatic injury reports (any severity level) was 4 times higher for men than women (age-adjusted IRR: 4.34; P<.001; 95% CI: 4.05, 4.66). The incidence of work-related traumatic injury reports was lower for Black/African-American workers than for white workers (age-adjusted IRR: 0.76; P=.004; 95% CI: 0.63, 0.92). The incidence of work-related traumatic injury reports was more than twice as high for Latinos compared with non-Latinos (age-adjusted IRR: 2.60; P<.001; 95% CI: 2.40, 2.82).

In summary, we observed significant upward trends in moderate and major traumatic injury reports for all gender, ethnicity, and age categories for the timeframe from 2003 through 2008, most of which persisted after we adjusted for age and changes in the underlying employed population. We also observed significant upward trends for several external causes (falls, machinery, and corrosive material/steam), and for amputations and traumatic brain injuries, which also persisted after adjusting for changes in the underlying employed population.

A previous study using Illinois Trauma Registry data found no significant declines in severe occupational injuries between 1995 and 2003[6] (in contrast with reports from national surveillance data), but neither did they observe upward trends as we did. There were several important differences between our study and theirs, aside from the states involved. First, the timeframes of the two studies only overlap by one year. However, the downward injury trends seen in the national employer-based Survey of Occupational Injuries and Illnesses (SOII) data have continued over both study timeframes for both states (for Washington, there was a nearly monotonic decline from 6.5 nonfatal injuries per 100 full-time workers in 2003 to 5.4 in 2008, a 17% overall drop).[52] There have also been monotonic downward trends in the number of compensable workers' compensation claims in Washington State during this time period, from 2.3 to 1.9 claims per 100 full-time workers, also a 17% overall drop (unpublished data). Trauma registry inclusion criteria differ between the states in several ways. For example, Illinois includes those admitted for at least 12 hours compared with 48 hours in Washington, Illinois includes dead on arrival (DOA) and ED deaths while Washington includes all inpatient deaths occurring during the trauma-related hospital stay as well as DOA and ED deaths, and only level I & II facilities report in Illinois while all designation levels, I through V, report in Washington. However, while these differences would be expected to affect observed rates, they shouldn't affect observed trends. We used American Community Survey (ACS)-based denominators for adjustment while the Illinois study used Current Population Survey (CPS)-based denominators; however, we ran a sensitivity analysis using both sources and differences were negligible. We also assessed the impact on our findings of (1) controlling for changes in the number and volume of reporting hospitals over the study timeframe and (2) excluding fatalities; both alternative approaches had negligible effect.

Perhaps the most important analytic difference is that we excluded minor injuries (those with an ISS under 9) from trend analyses, while the Illinois study included all injuries regardless of severity. We did this a priori, in order to limit inter- and intra-facility variation in reporting practices due to factors such as the highly variable skills and training among trauma registrars which can affect the accuracy and consistency of reporting decisions, financial incentives which can drive reporting, and EMS/ambulance transfers that may be related to geography and local resources but trigger inclusion regardless of severity. However, given the contrasts between our

findings and those in Illinois, we also ran our adjusted analyses (**Tables 3 and 4**) without excluding minor injuries. In doing so, we found little evidence for upward trends, generally speaking, but no evidence for downward trends. The age-adjusted mean annual percent increase for all injuries was 0.9%, but was not statistically distinguishable from zero (95% CI: -0.7%, +2.4%). Among subgroups, most upward-appearing trends were not statistically significant, and some appeared essentially flat. A notable exception was that the upward trend for Latino workers remained significant (mean annual percent change: 7.1%; P=.001; 95% CI: +2.8%, +11.6%), while the trend for non-Latino workers was essentially flat (mean annual percent change: 0.6%; 95% CI: -1.4%, +2.6%). There were no large or statistically significant downward trends. However, because our concerns about variation in reporting practices for minor injuries remain, we stand by our a priori decision to exclude minor injuries.

Despite these differences, the relative age-adjusted incidence rates for subpopulations (any injury severity level) were strikingly similar across the two studies. The all-year age-adjusted IRR for men compared with women was 4.34 (95% CI: 4.05, 4.66) in Washington, and 4.31 (95% CI: 4.14, 4.48) in Illinois. The all-year age-adjusted IRR for Black/African-American workers compared with white workers was 0.76 (95% CI: 0.63, 0.92) in Washington, and 0.71 (95% CI: 0.68, 0.76) in Illinois. The all-year age-adjusted IRR for Latino/Hispanic workers compared with other workers was 2.60 (95% CI: 2.40, 2.82) in Washington, and 2.44 (95% CI: 2.35, 2.54) in Illinois. This may be attributable to the confluence of more Latino/Hispanic representation and higher injury rates in the construction and agricultural sectors (particularly for contingent and precarious employment in those sectors).[53-56] Unfortunately, we cannot test this hypothesis using WTR data due to the absence of information about industry and occupation. Although we have stressed that the age-adjusted rates we have produced do not represent absolute injury rates and despite several differences in trauma registry inclusion criteria, it is still worth noting that when we included all injuries regardless of severity, the observed magnitude is not overly distant from that observed in Illinois (31.9 per 100,000 workers for Washington compared with 44.4 per 100,000 workers in Illinois).

There have been significant upward trends in the overall volume of WTR trauma reports since its inception (a three-fold increase from 1995-2009).[11] Reports produced by the WTR ascribe these trends to the aging population (especially falls and TBI in the elderly).[11] Because we are focused on the subset of work-related injuries, advanced age is less common and age adjustment should remove aging of the employed population as a contributor to the trends we observed. We can think of two alternative explanations for the observed upward trends. First, hospitals may be reporting increasingly higher proportions of their trauma cases over time. There is evidence that some aspects of reporting are in fact improving over time (e.g., decreasing amounts of missing data in many but not all fields). However, reporting is mandatory once hospitals are designated, and most hospitals had been reporting for some time prior to the timeframe of this study. The exclusion of minor injuries should have had the effect of removing the most borderline cases, those in which reporting inconsistencies might be more likely to occur for reasons described earlier. Second, it could be that higher proportions of all traumatic injuries are being directed to designated (reporting) hospitals over time. This is a goal of Washington's trauma system, "to deliver the "right" patient to the "right" facility in the "right" amount of time."[11] However, nearly all hospitals in the state have had a trauma designation since the WTR began and there are non-designated hospitals in only a single county (this county has a sophisticated EMS system, making misdirection unlikely). As a counterpoint to both of these alternative explanations, it did not appear that the WTR identified increasing proportions of two independently monitored indicators over this time period: (1) all Washington work-related fatalities (CFOI or FACE), or (2) all Washington work-related burn hospitalizations.

Our findings are also consistent with the possibility that rates of high-severity injuries may be increasing while rates of the more common lower severity injuries may be decreasing. SOII data do not contain severity information beyond missed work days. In contrast to the downward trends observed for all Washington State WC claims, those involving immediate hospitalization did not display a strong or monotonic downward trend for this time period. There were 55.8 claims involving immediate hospitalization per 100,000 full-time workers in 2003 and 51.4 in 2008, an 8% overall drop; however, there were increases in some years and no significant overall trend using Poisson modeling (unpublished data). Another possible explanation for our findings might be an expansion over time in employment falling outside the scope of WC coverage and/or SOII surveys. The WTR work-related indicator is minimally defined, and identifies an unknown number of work-related injuries that may not be captured by most occupational injury data sources (e.g., injuries among self-employed workers, family farms, federal employees, household workers, etc.). Lastly, we were limited to 6 years of WTR data, which is not a long timeframe for trend assessment, and the trend for WC hospitalized injury claims did appear particularly flat from 2003 to 2008 in contrast to the years before and after that time period. Going into the future, as the WTR continues to mature, it may become a stronger long-term source for occupational injury trend assessment. However, ongoing changes in WTR inclusion criteria may continue to pose challenges.

We conducted additional analyses to further investigate and describe trends in the disproportionate burden of traumatic occupational injuries sustained by Latinos in Washington State. We address the following research question with regard to traumatic injuries reported to the WTR: Controlling for representation of Latinos in the relevant underlying labor force, is there evidence of an increasing trend from 1998 to 2008 in the odds that a comparable work-related traumatic injury was sustained by a Latino rather than by a non-Latino? This approach allows us to examine relative trends by ethnicity while avoiding the challenges posed by injury rate calculations based on the WTR data.

Characteristics of work-related traumatic injuries reported to the WTR (1998 through 2008) were summarized by ethnicity and are presented in **Table 5**.

TABLE 5. Characteristics of work-related traumatic injuries reported to the WTR, by ethnicity

Characteristic	Overall (N=7,046)		Non-Latino (N=5,821)	Latino (N=1,225)	P-value
	N	%	%	%	
Gender					.03
Male	6,299	89.4	89.0	91.2	
Female	747	10.6	11.0	8.8	
Age					<.0005
16-24	1,063	15.1	13.1	24.5	
25-34	1,572	22.3	19.9	33.9	
35-44	1,694	24.0	24.3	22.9	
45-54	1,549	22.0	24.3	11.2	
55-64	855	12.1	13.6	5.3	
65 and older	313	4.4	4.9	2.3	

Characteristic	Overall		Non-Latino	Latino	P-value
	N	%	%	%	
Payer					<.0005
Labor & Industries (L&I) only	4,601	65.3	62.5	78.6	
L&I and other private/government insurance	521	7.4	7.8	5.5	
Other private/government insurance only	1,376	19.5	22.0	7.8	
None (self-pay, charity)	304	4.3	4.2	5.0	
No payer information (missing)	244	3.5	3.5	3.2	
Injury Severity Score					.009
Minor (1-8)	2,956	42.1	41.5	45.0	
Moderate (9-15)	2,532	36.1	36.0	36.4	
Major (16-75)	1,529	21.8	22.5	18.7	
Amputation (any type)	543	7.7	7.4	9.1	.05
Upper or lower extremity amputation	97	1.4	1.1	2.9	<.0005
Traumatic brain injury	1,549	22.0	22.8	18.2	<.0005
Burn	697	9.9	10.0	9.6	NS
Fatality (death on arrival or in-hospital)	209	3.0	3.3	1.6	.002
External cause of injury					<.0005
Falls	2,557	36.3	36.6	34.8	
Machinery	1,019	14.5	13.2	20.4	
Motor vehicle traffic	642	9.1	9.8	5.8	
Cutting/piercing objects	340	4.8	4.5	6.5	
Struck by object	858	12.2	12.7	9.7	
Caught between objects	314	4.5	4.3	5.3	
Electrocution	135	1.9	2.2	0.5	
Corrosive material/steam	265	3.8	3.3	5.8	
Homicide/assault	99	1.4	1.6	0.7	
Overexertion/movement-related	35	0.5	0.5	0.7	
Fire/flames	163	2.3	2.5	1.5	
Explosive materials	50	0.7	0.7	0.7	
Animal bites	42	0.6	0.6	0.7	
Other/unspecified	527	7.5	7.6	7.1	
Place of injury					<.0005
Home	414	5.9	6.6	2.4	
Farm	404	5.7	3.8	15.2	
Mine/quarry	18	0.3	0.3	0.0	
Industrial	4,080	57.9	57.5	59.7	
Sports/recreation	110	1.6	1.7	0.8	
Street/highway	659	9.4	10.1	5.6	
Public building	208	3.0	3.1	2.0	
Residential institution	64	0.9	1.1	0.1	
Other specified	621	8.8	9.2	6.9	
Missing/unspecified	468	6.6	6.5	7.4	

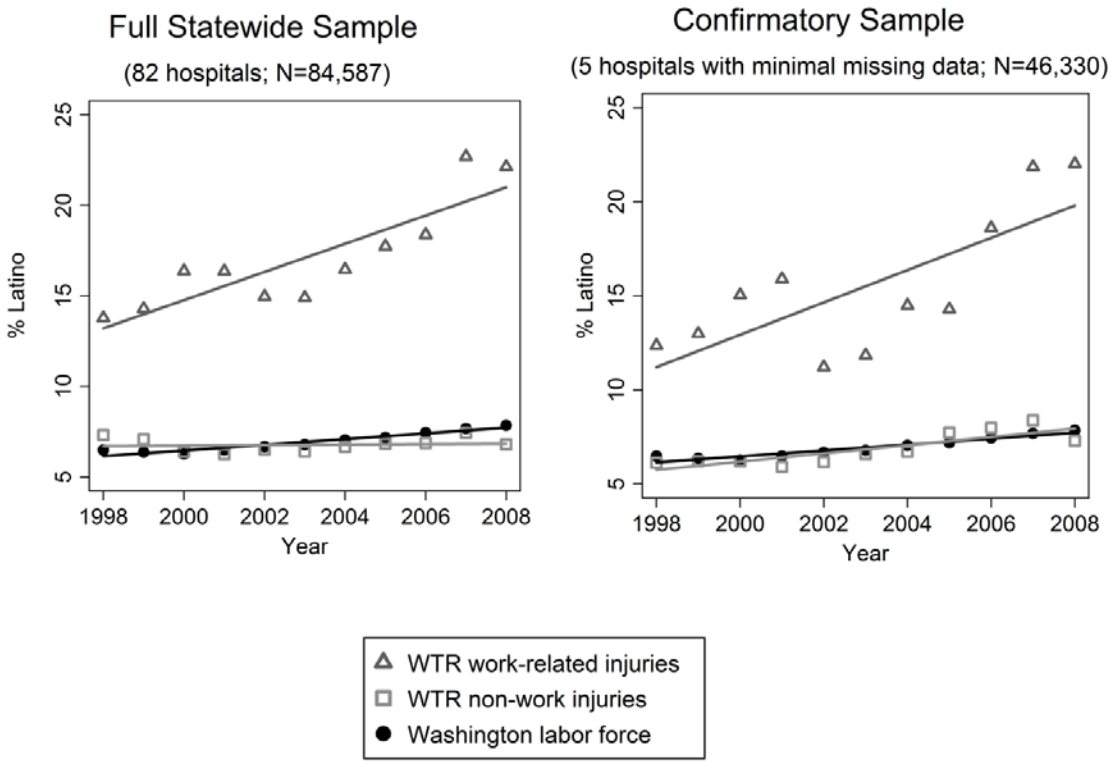
The ethnicity distribution and numbers of work-related and non-work injuries by calendar year are presented in **Table 6**. Across all 11 years, 17.4% of work-related injuries were sustained by Latinos, compared with 6.8% of non-work injuries (p<.0005). In order to illustrate the striking contrasts in trends, **Figure 1** displays the information in **Table 6** graphically for each of the 2 samples. The trend lines represent the unadjusted percent of injuries that are sustained by Latinos (vs. non-Latinos), and are independent of trends in injury rates. It is evident from this figure that both the magnitude of the injury burden on Latinos (relative to non-Latinos) and trends in Latino representation differ substantially between work-related and non-work injuries. It appears that Latinos both carry a higher share of the injury burden and have a steeper increasing trend in the injury burden they carry for work-related injuries, relative to both non-work injuries and underlying Latino representation in the labor force.

TABLE 6. Latino representation by year

Calendar year	Washington labor force	All WTR injuries (N=85,322)		Non-work injuries (N=77,541)		Work-related injuries (N=7,046)	
	% Latino	N	% Latino	N	% Latino	N	% Latino
1998	6.5	5,064	8.0	4,332	7.3	508	13.8
1999	6.4	5,491	7.9	4,869	7.1	581	14.3
2000	6.3	6,596	7.4	5,889	6.4	623	16.4
2001	6.5	7,258	7.0	6,541	6.3	605	16.4
2002	6.7	7,324	7.3	6,619	6.5	628	15.0
2003	6.8	7,615	7.2	6,981	6.4	604	14.9
2004	7.1	8,163	7.5	7,503	6.7	626	16.5
2005	7.2	8,636	7.7	7,961	6.9	637	17.7
2006	7.5	9,636	7.9	8,859	6.9	740	18.4
2007	7.7	9,494	8.7	8,691	7.4	780	22.7
2008	7.9	10,045	7.9	9,296	6.8	714	22.1
All-year mean	7.0		7.7		6.8		17.4

We quantified these differences using logistic regression with robust variance estimates to model mean annual percent change in the odds that a comparable injury was sustained by a Latino rather than a non-Latino, controlling for demographics, payer, and injury-related factors as well as Latino representation in the relevant underlying labor force. The results of these models are presented in **Table 7**. We also tested log-linear models (Poisson and log binomial), but settled on logistic regression models due to better model fit and performance.[57] The results for the full sample and the confirmatory sample were substantially similar for all models, with the full sample generally providing more conservative results. There was an estimated mean annual increase of 4.2% in the odds that an injury was sustained by a Latino rather than a non-Latino (p=.007), and 5.1% when place and external cause of injury were included in the model (p=.001). When the model was stratified by place of injury, only the industrial/mine/quarry category exhibited a significantly increasing trend (8.3%; p<.0005). Focusing in on this category and stratifying further by external cause, only falls exhibited a significantly increasing trend (12.7%; p=.005).

FIGURE 1. Trends in the Latino share of the traumatic injury burden



We found not only a disparity in the burden of work-related traumatic injuries sustained by Latinos relative to non-Latinos, but also that the disparity has increased over time. We found a 5% mean annual increase in the odds that a comparable work-related traumatic injury was sustained by a Latino (p=.007). In contrast, the unadjusted magnitude and trend in non-work injuries appeared to more closely follow population trends. Although several studies have reported a disproportionate rate of occupational injuries for Latinos, trends over time in the relative rates of occupational injuries among Latinos compared with other workers have not been well-studied. This study provides evidence that Latinos in Washington State bear an *increasingly* disproportionate burden of severe work-related traumatic injuries, accounting for a rising share of such injuries over time even after accounting for demographic trends.

The data available to us do not reveal whether the increased burden on Latinos is due mainly to distributional changes in employment patterns or also due to differential risk for Latinos even within specific work settings, due to the lack of information on industry or occupation in the WTR. However, in using place of injury and external cause of injury, it appeared that falls in industrial/mine/quarry locations were the strongest contributor to the increasing disparity over time.

TABLE 7. Burden of work-related injuries sustained by Latinos relative to non-Latinos

Model*	Mean annual trend in the odds that a work-related injury was sustained by a Latino (rather than a non-Latino)					
	Full sample (N=7,017)			Confirmatory sample (N=4,624)		
	N	Mean annual % change	P-value	N	Mean annual % change	P-value
All places and external causes of injury	6775	4.2% ↑	.007	4434	4.8% ↑	.02
All places and external causes of injury, controlling for place and external cause	6775	5.1% ↑	.001	4434	5.8% ↑	.003
Stratified by place of injury						
Industrial/mine/quarry	3941	8.3% ↑	<.0005	2930	8.1% ↑	.001
Farm	392	6.3% ↓	NS	178	10.7% ↓	NS
All other or unspecified	2442	1.2% ↑	NS	1326	4.9% ↑	NS
Industrial/mine/quarry only, stratified by external cause						
Falls	1389	12.7% ↑	.005	966	18.5% ↑	.004
Machinery	774	4.8% ↑	NS	581	6.0% ↑	NS
Objects: struck/cut/caught	1051	7.0% ↑	NS	771	4.2% ↑	NS
Fire/elect/explosive/corrosive/steam	426	6.9% ↑	NS	404	6.2% ↑	NS
All other or unspecified**	301	10.1% ↑	NS	208	7.7% ↑	NS

*All logistic regression models included: year (continuous), % Latino in relevant Washington labor force stratum, gender, age category, Injury Severity Score (continuous), L&I as an expected payer, and other private/government insurance as an expected payer.
**Expanded to include motor vehicle traffic due to smaller numbers within Industrial/mine/quarry place of injury.

Specific Aim 2: ***Explore and document the feasibility and utility of linking WTR data to Washington State WC claims data to enhance state-based occupational injury research.***

2a. Use deterministic and probabilistic linkage algorithms to link WTR injuries to Washington State WC claims. Compare linkage rates and resource requirements with simpler deterministic linkage methods.

Linkage procedures are described in the Methodology/ Data Linkage and Deduplication of Injury Reports section above.

2b. Describe concordance between WTR work-related injuries and Washington State WC claims.

i. Describe the numbers of work-related injuries captured by the WTR alone, L&I claims data alone, and by both. Calculate the proportion of WTR work-related injuries having WC claims filed with L&I, and conversely the proportion of L&I claims represented in the WTR. Assess the sensitivity and false negative rate of the WTR work-related field.

Figure 2 presents the details of the linkage between WTR reports and claims data (using counts of injury events), stratified by WTR-based work-related and payer status.

FIGURE 2. Injury linkage report, by data source and WTR work-related/payer status

	Not in L&I Claims Data		**In L&I Claims Data***		**Totals**	
Not in WTR Data	*Non-traumatic injury* *Treated at non-reporting facility* *Trauma not meeting WTR criteria* *Death without EMS activation* **unobserved**	**A**	Non-traumatic injury Treated at non-reporting facility Trauma not meeting WTR criteria Death without EMS activation **665,880**	**F**	**665,880**	**T1**
In WTR Data Work-related=No Payer≠L&I	Non-work injuries **114,484**	**B**	[No work injuries should fit this pattern] **478**	**G**	**114,962**	**T2**
In WTR Data Work-related=No Payer=L&I	L&I crime victim claims **888**	**C**	[No work injuries should fit this pattern] **590**	**H**	**1,478**	**T3**
In WTR Data Work-related=Yes Payer≠L&I	*Work injury lacking L&I claim* Exempt employment ** **1,938**	**D**	[No work injuries should fit this pattern***] **582**	**I**	**2,520**	**T4**
In WTR Data Work-related=Yes Payer=L&I	*Work injury lacking L&I claim* L&I employees (excluded) Medical aid-only claims (excluded) **1,085**	**E**	Trauma treated at reporting facility **5,580**	**J**	**6,665**	**T5**
Totals	**118,395**	**T6**	**673,110**	**T7**	**791,505**	**T8**

*Accepted and rejected claims (some work-related injuries may not be eligible for WC).

**Exempt employment includes federal employees, sole proprietors, employment at a private home, etc.

***But L&I may not yet have been identified as the payer at the time of initial trauma care.

Notes: These numbers were calculated at the unduplicated "injury event" level. Italics indicate potential under-reported/under-claimed work injuries. Injury events were considered work-related if any related WTR report indicated work-relatedness, and LNI payer was assigned if LNI appeared in either payer field for any related WTR report. Matching failures (records that should have been linked but weren't) could show up in cells B, C, D, E, or F.

To evaluate the WTR work-related indicator, we calculated sensitivity and false negative rates using linkage to an accepted WC claim as the gold standard (there was little difference when rejected claims were included). The overall sensitivity of the work-related indicator was 87.0% (95% CI: 86.2%, 87.8%); it mis-identified only 13% of linked claims as not being work-related.

Sensitivity and false negative rates varied significantly by injury location and external cause (see **Table 8**). We do not focus on specificity calculations because a significant level of non-linkage was expected for a variety of reasons (exempt employment, study exclusions, and workers who did not file a WC claim) and would be an inappropriate gold standard for non-work-relatedness. However, it does bear noting that observed specificities were high; the observed overall specificity of the WTR work-related indicator was 97.2%. This can be considered a lower bound since cases incorrectly classified as false positives due to the absence of a WC claim for a truly work-related injury would push the observed specificity lower than the truth.
The percent of missing data decreased over time, but sensitivity estimates appeared fairly stable over time. Although sensitivity varied by hospital, there was no apparent correlation between sensitivity and facility characteristics (i.e., trauma designation level, volume of trauma reports) that might indicate that more experience/resources tended to improve the validity of the WTR work-related indicator.

TABLE 8. Sensitivity and false negative rates by injury location and external cause

	N	Sensitivity	95% CI	False negative	95% CI
Place of injury		%	%	%	%
Home	44,365	63	57 - 68	37	32 - 43
Farm	1,153	95	91 - 97	5	3 - 9
Mine/quarry	80	100	85 - 100	0	0 - 15
Industrial	5,599	96	95 - 96	4	4 - 5
Sports/recreation	6,665	59	49 - 70	41	30 - 51
Street/highway	38,997	61	58 - 65	39	35 - 42
Public building	4,021	85	80 - 89	15	11 - 20
Residential institution	5,175	86	73 - 94	14	6 - 27
Other Specified	7,752	84	81 - 87	16	13 - 19
Unspecified	11,818	82	78 - 85	18	15 - 22
External cause					
Falls	55,367	86	84 - 87	14	13 - 16
Machinery	1,782	97	96 - 98	3	2 - 4
Road accidents	33,395	63	59 - 66	37	34 - 41
Cutting/piercing objects	1,577	94	91 - 97	6	3 - 9
Struck by object	3,397	95	93 - 96	5	4 - 7
Caught between objects	724	96	93 - 98	4	2 - 7
Electrocution	182	97	91 - 99	3	1 - 9
Corrosive material/steam	1,062	96	92 - 98	4	2 - 8
Homicide/assault	9,830	77	68 - 85	23	15 - 32
Overexertion/movement-related	881	86	73 - 95	14	5 - 27
Fire/flames	1,991	93	87 - 97	7	3 - 13
Explosive materials	385	94	79 - 99	6	1 - 21
Animal bites	727	86	70 - 95	14	5 - 30
Other specified	14,144	83	79 - 86	17	14 - 21
Missing/not specified	181	80	28 - 99	20	1 - 72

In addition to the WTR work-related indicator, we also assessed E-codes and payer as potential methods to identify work injuries. **Table 9** presents sensitivity estimates for each of these 3 indicators, as well as all possible combinations. The E-code indicator had very low sensitivity on its own (59.6%, 95% CI: 58.4, 60.8). Because the low sensitivity might have been due to the limited types of injuries that can be classified by the E-code indicator (for example, the E-codes for motor vehicle traffic do not carry any usable work-relatedness information), we checked its sensitivity after limiting the sample to only those injuries that the E-code indicator could classify but we did not observe great improvement (68.9%, 95% CI: 67.7, 70.1). Payer had the highest sensitivity of the three solo indicators (88.6%, 95% CI: 87.8, 89.3). By definition, combining all three indicators identified the most work-related injuries and resulted in the highest sensitivity (95.6%, 95% CI: 95.1, 96.1).

TABLE 9. Sensitivity of all indicators, individually and in combination

Indicator	**For injuries linked to a compensable WC claim**		
	N*	**Sensitivity**	**95% CI**
W: WTR work-related indicator	5,805	87.0	86.2 - 87.8
L: L&I noted as payer	5,911	88.6	87.8 - 89.3
E: ICD-9-CM E-code indicator	3,978	59.6	58.4 - 60.8
WL	6,353	95.2	94.7 - 95.7
WE	5,974	89.5	88.8 - 90.2
LE	6,199	92.9	92.3 - 93.5
WLE	6,381	95.6	95.1 - 96.1

CI, confidence interval.
*Number both identified by indicator as being work-related and verified by linkage to a compensable WC claim.

The Venn diagram in **Figure 3** depicts the overlaps and discordancies between the three indicators (regardless of linkage to a WC claim). Of the 11,575 injuries identified as work-related by any of the three methods, 37% were identified as work-related by all three indicators. Another 31% were identified by some combination of two of the indicators. Notably, only 3.1% of those identified solely by the E-code indicator were linked to a compensable WC claim, compared with 12.5% of those identified solely by the WTR work-related indicator and 31.5% of those identified solely by payer.

Due to the lack of a suitable gold standard for specificity, we then assessed the issue of false positives by examining patterns within the three subsets of injuries that were identified as work-related solely by one of the three indicators (and not the other two) and that also did not link to a compensable WC claim (see **Table 10**). One striking pattern was that fully 58.3% of the unlinked injuries identified as work-related solely by L&I as payer ("L-only") involved a homicide or assault (compared with only 1.4% for all linked injuries). Another striking pattern was that 46.4% of the unlinked injuries identified as work-related solely by the E-code indicator ("E-only") occurred on non-residential areas of a farm (compared with only 4.1% for all linked injuries). Of those farm-based injuries, 52% involved falls and 20% involved animal bites. Only 4% of "E-only" farm-based injuries were sustained by Latinos, compared with 66% of linked farm-based injuries ($p<.0001$). Fully 37% of "E-only" farm-based injuries were sustained by those 65 and over, compared with only 4% of linked farm-based injuries ($p<.0001$).

FIGURE 3. Venn diagram showing overlap of the three work injury indicators (areas not to scale). The denominator for all percentages shown is the total number of work injuries identified using any of the three indicators (N = 11,575).

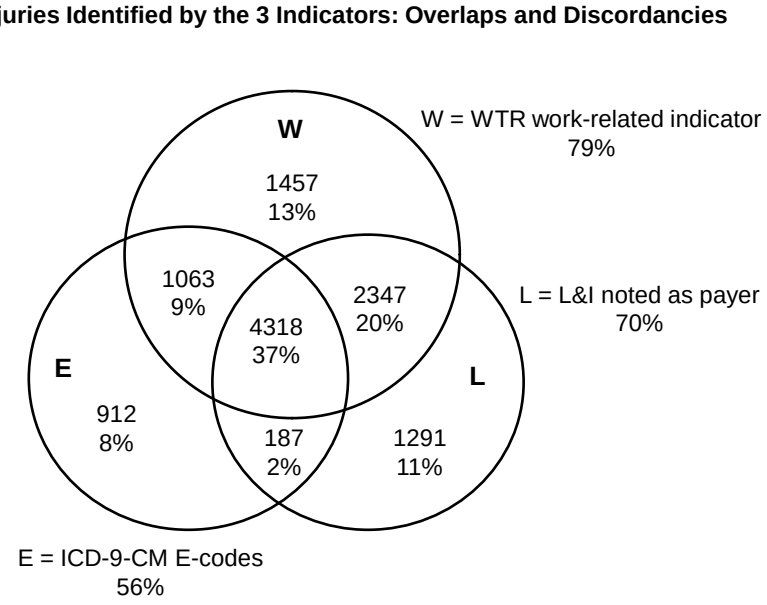


TABLE 10. Characteristics of injuries identified as work-related solely by one indicator (and not linked to a compensable WC claim), compared with all linked injuries

Characteristic	W only (N=1,275)		L only (N=884)		E only (N=884)		All linked injuries (N=6,673)	
	Category	%	Category	%	Category	%	Category	%
Age	≥65	12.2	≥65	3.3	≥65	28.5	≥65	3.6
Place of injury								
Most common	Other	22.8	Home	27.5	Farm	46.4	Industrial	57.2
2nd most common	Home	20.8	Street/ highway	26.0	Industrial	33.3	Street/ highway	11.9
External cause								
Most common	Falls	38.1	Homicide/ assault	58.3	Falls	51.7	Falls	39.1
2nd most common	Motor vehicle traffic	19.6	Falls	15.4	Animal bites	11.2	Machinery	14.5

WC, workers' compensation; W, WTR work-related indicator; L, L&I noted as payer; E, ICD-9-CM E-code indicator.

ii. Describe the types of injuries involving WC claims that are most completely represented in the WTR.

Overall, fewer than 2% of injuries with compensable WC claims linked to the WTR due to the relatively minor nature of most work-related injuries; however, about 10% of all amputations and more than a quarter of non-fingertip amputations were linked. Progressively more severe injury types were linked at higher rates; for example, among all amputations, 65% of those observed to result in total permanent disability (TPD) were linked to the WTR. However, even the most severe and disabling injuries were not always linked to the WTR, in part due to trauma treated at non-reporting hospitals, out-of-state injuries, and factors other than anatomic injury severity that can result in TPD.

We also compared the raw number of work-related trauma reports involving fatalities, burns, traumatic brain injury (TBI), and amputations with other available sources. There were 247 work-related fatalities identified in the WTR from 1998 through 2008, compared with 942 identified by the Fatality Assessment and Control Evaluation (FACE) program, run by L&I's Safety and Health Assessment and Research for Prevention (SHARP) program, and 991 identified by the Census of Fatal Occupational Injuries (CFOI) during the same years. The WTR therefore captured about a quarter of the work-related fatalities occurring in Washington (a study in Illinois reported an estimate of about 20% for that state[6]). Trauma registries would be expected to capture only a fraction of the fatalities captured by death registries because work-related deaths can occur in any setting. Many work-related trauma deaths occur in the field; a medical examiner or emergency personnel may declare death and the worker may never arrive at a reporting hospital. We identified 409 hospitalized work-related burns in the WTR from 2003-2008, compared with 502 identified by SHARP's hospitalized work-related burn surveillance program during the same years (case definitions were roughly comparable though hospital coverage differed). We identified 712 cases of work-related TBI in the WTR from 1998-2002, compared with 797 cases identified by a different study using WC data during the same years[58] (the case definitions and available populations were somewhat different). TBI is an injury type that might more often involve EMS transfer, trauma team activation, and/or extended hospital observation time and thus be quite likely to be reported to the WTR compared with other injury types. According to national estimates, 16% of those treated in an ED for TBI are hospitalized and another 3% die.[30] We identified 434 work-related amputations, including 55 upper extremity amputations and 19 lower extremity amputations in the WTR from 1998-2005, compared with 2,528 total work-related amputations, 45 upper extremity amputations, and 22 lower extremity amputations identified by a different study using WC data from 1997-2005 (identified using ANSI Z16 codes).[59] Again, the case definitions and available populations were somewhat different. As would be expected based on severity, the counts of upper extremity and lower extremity amputations were much more similar across WTR and WC data sources than were the counts for all amputations, many of which may not require hospitalization (e.g., fingertip amputations).

We took a particularly close look at TBI. About a quarter of TBI cases identified using WC-based ICD-9-codes were captured by the WTR. TBI is one of the most common and costly occupational injuries.[60,61] Yet few U.S.-based studies have focused on work-related TBI, and no national estimates of the incidence of nonfatal occupational TBI were identified. This deficiency is due in part to the difficulty inherent in reliably identifying work-related TBI using administrative data sources.[62] The structure of the OIICS requires coders to identify the most severe injury and default to multiple injury/multiple body part categories when there is conflict or insufficient information, which can obscure the presence of individual injuries such as TBI. During this project, we noted an apparent undercount of TBI using the OIICS when compared with ICD-9-CM codes.[63] This motivated further exploration of this issue using the clinical diagnosis

information available from the WTR, linked with WC claims containing OIICS codes. WTR-based ICD-9-CM codes provided a gold standard (superior to the ICD-9-CM codes available from WC billing data) to assess the potential undercount of TBI inherent in relying on the OIICS. Underestimating the prevalence of such a potentially severe and disabling injury could have important ramifications for prevention efforts.

There were 6,639 linked work-related injury events (for 6,645 workers) with available OIICS codes. Overall, 19.8% of work-related injuries reported to the WTR and linked to a WC claim involved TBI (according to WTR-based ICD-9-CM codes). By cause of injury, 36.7% of motor vehicle traffic incidents and 25.4% of falls involved TBI. Among work-related injury fatalities, 59.5% overall involved TBI, as did 88.2% of fatal falls and 66.0% of fatal motor vehicle traffic incidents. Most of the 117 fatal TBI cases were due to falls (51.3%) and motor vehicle traffic incidents (27.4%). Of all linked work-related TBI in this sample, 8.9% were fatal and 91.1% were nonfatal; 34.6% of the sample was isolated TBI and 65.4% was TBI with other trauma.

Solely for purposes of this study, six OIICS-based TBI case definitions were defined as shown in **Figure 4**. Case definition 1 (CD1) was the narrowest, and CD2 through CD6 were progressively less restrictive (CD6 was so loose as to arguably be meaningless with respect to TBI, and is presented only for purposes of illustration). Counts of TBI captured by various combinations of OIICS nature and part of body categories were calculated separately for: (1) all TBI, (2) fatal TBI, and (3) isolated TBI. Case classification statistics were estimated for each of the six case definitions. The number and percent of cases captured by each of the six case definitions. The number and percent of cases captured by each of the six case definitions were calculated for several subsets of TBI (fatal, nonfatal, isolated TBI, TBI with other trauma).

FIGURE 4. OIICS-based case definition (CD) criteria used for TBI case classification estimates. Numbers in the first and second rows indicate OIICS nature and body part codes respectively. All existing subgroups of each code shown were subsumed unless otherwise indicated. An "X" indicates each nature/body part combination that was included by the case definition on the same row.

Nature:	Intracranial	Intracranial and internal organ	Fractures				Multiple trauma		Symptoms, signs, ill-defined		Nonclassifiable	
	06	086	012				08		4		9999	
Body part:	Any	Any	Cranial/ skull	Head (not ears/face)	Head	Multiple	Head	Multiple	Head	Multiple	Head	Multiple
			01	00/01/08	0	8	0	8	0	8	0	8
CD1	X	X	X									
CD2	X	X	X	X								
CD3	X	X	X	X	X							
CD4	X	X	X	X	X		X					
CD5	X	X	X	X	X		X		X		X	
CD6	X	X	X	X	X	X	X	X	X	X	X	X

Figures 5, 6, and 7 display the counts of work-related TBI cases captured by various OIICS nature and part of body combinations, for all TBI (N=1,313), fatal TBI (N=117) and isolated TBI (N=454) respectively.

FIGURE 5. Count of all TBI cases captured by each OIICS nature/part of body combination (N=1,313). OIICS codes not listed contained no TBI cases; all existing subgroups of each listed OIICS code were subsumed unless otherwise indicated.

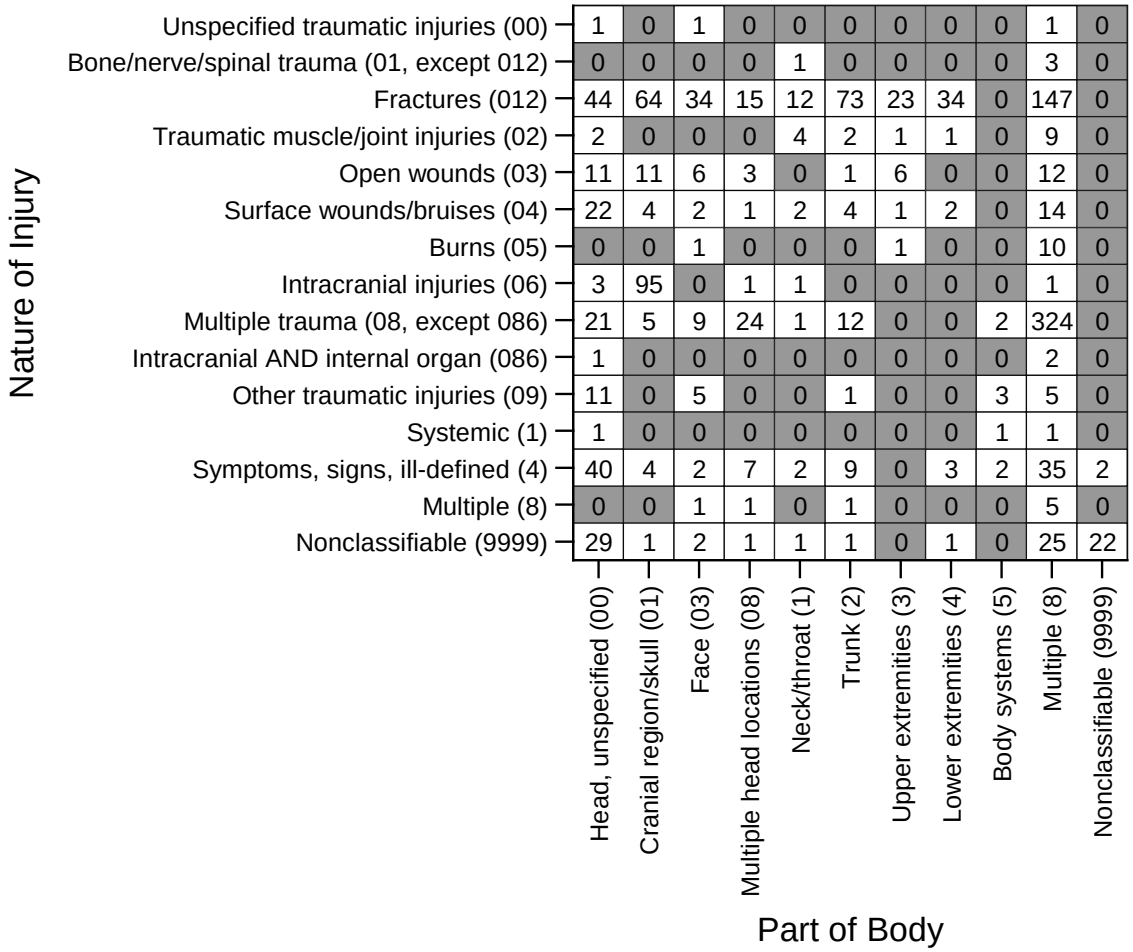


FIGURE 6. Count of fatal TBI cases captured by each OIICS nature/part of body combination (N=117). OIICS codes not listed contained no TBI cases; all existing subgroups of each listed OIICS code were subsumed unless otherwise indicated.

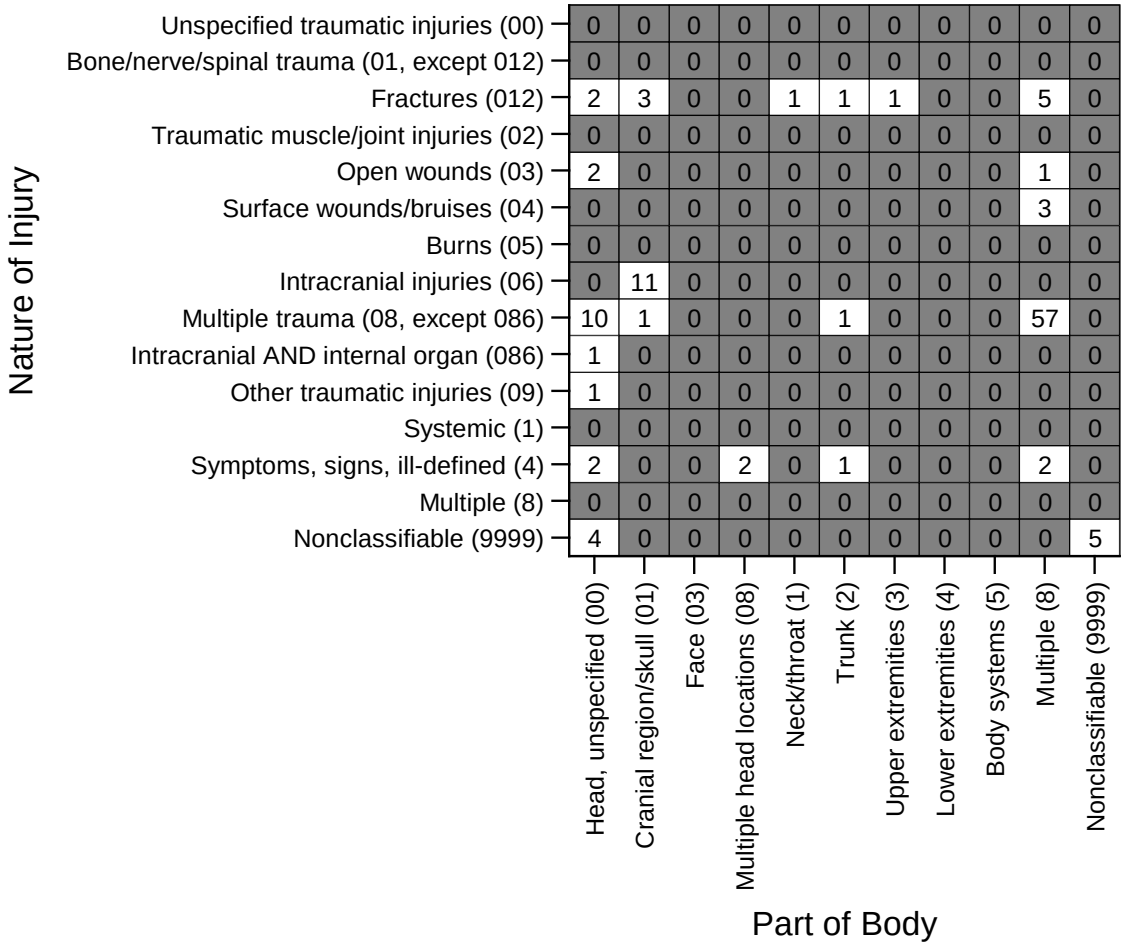
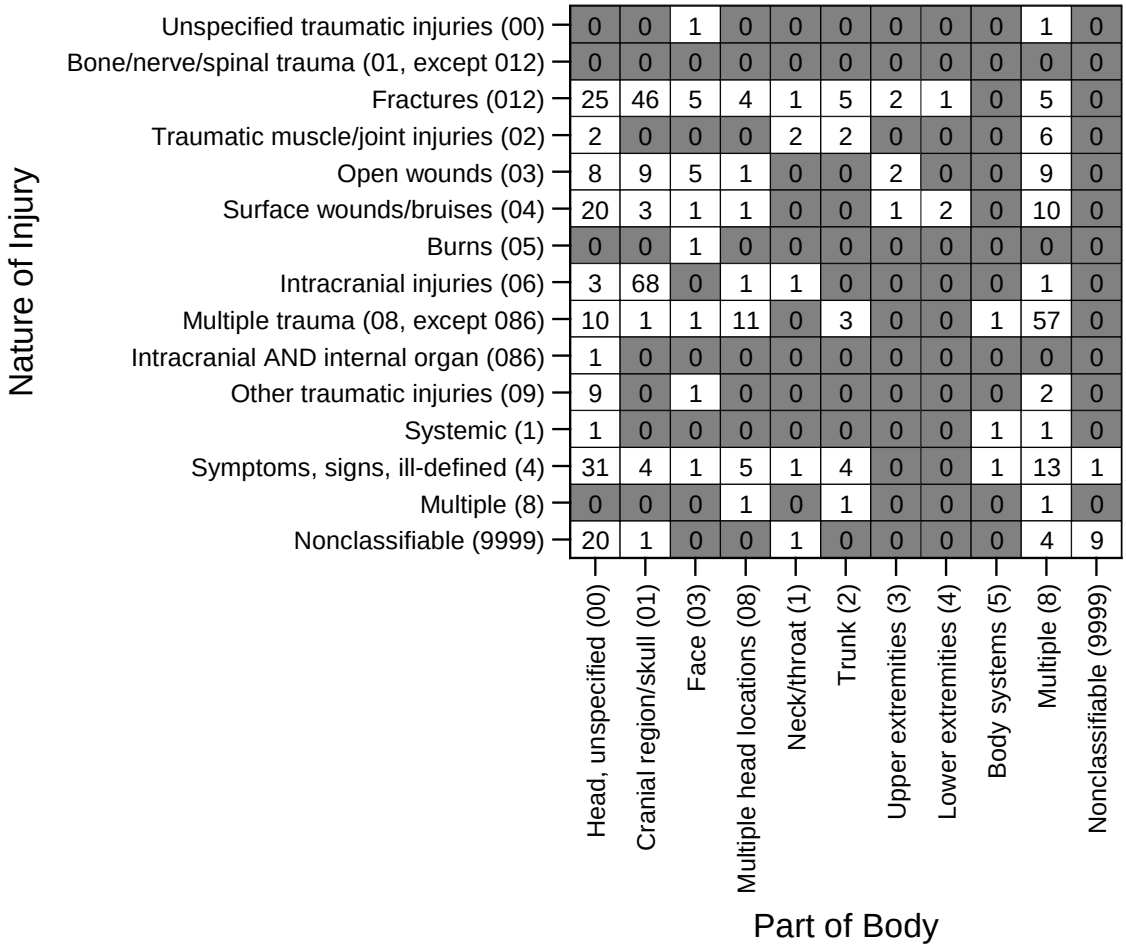


FIGURE 7. Count of isolated TBI cases captured by each OIICS nature/part of body combination (N=454). OIICS codes not listed contained no TBI cases; all existing subgroups of each listed OIICS code were subsumed unless otherwise indicated.



A high proportion of TBI was obscured within the categories of multiple traumatic injuries and/or multiple body parts, particularly for all TBI (**Figure 5**) and fatal TBI (**Figure 6**), but even for isolated TBI (**Figure 7**). This appeared to be the driver for the very low sensitivity exhibited by all case definitions except for CD6, which included the "multiple" categories (**Table 11**). On the other hand, as shown in **Table 11**, all case definitions were highly specific (CD6 somewhat less so).

TABLE 11. Case classification for OIICS-based case definitions (N=6,639*)

Case definition (CD)	True positives n	False positives n	Sensitivity	Specificity	AUC	PV+	PV-
CD1	168	17	12.8	99.7	0.56	90.8	82.3
CD2	227	23	17.3	99.6	0.58	90.8	83.0
CD3	261	61	19.9	98.9	0.59	81.1	83.3
CD4	320	70	24.4	98.7	0.62	82.1	84.1
CD5	406	99	30.9	98.1	0.65	80.4	85.2
CD6	937	898	71.4	83.1	0.77	51.1	92.2

* All linked work-related injuries having available OIICS codes.
AUC, area under the receiver operating characteristic curve; PV+, positive predictive value; PV-, negative predictive value; CD, case definition.

Table 12 shows the number and percentage of work-related TBI cases correctly identified using the six case definitions for several categories of TBI (fatal/nonfatal; isolated/with other trauma). CD1, which served as the initial case definition based on strong face validity, identified only 13% of all fatal/nonfatal TBI. It identified well under a third of isolated TBI and only 6% of TBI with other trauma. CD5 identified less than a third of TBI cases in every TBI category, with the exception of isolated TBI for which it identified 53%. Only CD6, which classified any multiple trauma to multiple body parts as TBI, identified more than two-thirds of TBI cases.

TABLE 12. True positive cases of work-related TBI identified using OIICS-Based case definitions (CD), by TBI category

TBI category	TBI* N	CD1 n (%)	CD2 n (%)	CD3 n (%)	CD4 n (%)	CD5 n (%)	CD6 n (%)
All TBI	1,313	168 (12.8)	227 (17.3)	261 (19.9)	320 (24.4)	406 (30.9)	937 (71.4)
Fatal TBI	117	15 (12.8)	17 (14.5)	17 (14.5)	28 (23.9)	36 (30.8)	100 (85.5)
Nonfatal TBI	1,196	153 (12.8)	210 (17.6)	244 (20.4)	292 (24.4)	370 (30.9)	837 (70.0)
Isolated TBI	454	121 (26.7)	150 (33.0)	155 (34.1)	178 (39.2)	240 (52.9)	319 (70.3)
TBI with other trauma	859	47 (5.5)	77 (9.0)	106 (12.3)	142 (16.5)	166 (19.3)	618 (71.9)

* TBI identified using WTR-based ICD-9-CM codes according to the CDC case definition.
CD, case definition.

Table 13 presents the attributable cause distribution for work-related TBI using the WTR-based case definition and each of the OIICS-based case definitions (with the exception of CD6, which was defined too broadly for this purpose). All case definitions identified the primary cause of work-related fatal/nonfatal TBI as falls. However, the WTR-based definition identified motor vehicle traffic incidents as the second most frequent cause, while all OIICS-based definitions identified the struck by/against category as the second most frequent cause, with motor vehicle traffic incidents third.

TABLE 13. Attributable cause of work-related TBI (percentage distribution) for each WTR and OIICS-based case definition (CD)

Cause of injury	TBI* (N=1,313)	CD1 (N=185)	CD2 (N=250)	CD3 (N=322)	CD4 (N=390)	CD5 (N=505)
Motor vehicle traffic	20.4	11.9	10.0	11.2	10.8	10.9
Pedal cyclist, other	0.2	-	-	-	-	0.2
Pedestrian, other	0.5	-	-	0.3	0.3	0.4
Transport, other	3.7	1.6	2.8	2.2	3.1	4.0
Firearm	0.6	-	-	-	-	0.2
Poisoning	-	-	-	-	0.3	0.2
Falls	50.3	58.4	56.4	49.4	46.4	46.9
Fire/burn	0.3	-	-	-	0.3	0.6
Cut/pierce	1.1	1.1	0.8	1.2	1.3	1.8
Struck by/against	14.8	16.2	19.6	24.5	25.6	24.0
Machinery	4.3	8.1	7.2	7.5	7.7	6.7
Natural/environmental	0.3	0.5	0.4	0.3	0.3	0.4
Other specified	2.9	1.6	2.0	2.8	3.3	3.2
Other specified, NEC	0.2	0.5	0.4	0.3	0.5	0.4
Unspecified	0.3	-	0.4	0.3	0.3	0.2

* TBI identified using WTR-based ICD-9-CM codes according to the CDC case definition.
CD, case definition; NEC, not elsewhere classifiable.

No guidelines exist for case ascertainment of fatal or nonfatal TBI using the OIICS, but recent progress has been made in estimating the national incidence of fatal occupational TBI using CFOI data in combination with an OIICS-based case definition.[62] We did not identify any reasonably sensitive OIICS-based case definition for TBI. Though highly specific, all case definitions used in this study had low sensitivity, capturing less than a third of the fatal or nonfatal work-related TBI identified using the clinical diagnoses codes available in the trauma registry (with the exception of CD6, which lacked face validity and was included only for purposes of illustration). A high proportion of TBI was obscured within the categories of multiple traumatic injuries and/or multiple body parts. In addition, OIICS-based case definitions captured only about half of the isolated TBI cases, presumably due to deficiencies in the information available to OIICS coders or coding errors (which might vary by jurisdiction or database).

iii. Describe whether concordance is better in particular geographic regions.

There was a fair amount of variability by geographic region, but no interesting patterns emerged.

2c. Evaluate the association of WTR-based severity measures with the limited severity measures available in L&I claims data, and evaluate whether WTR-based severity measures add value over and above L&I-based data for control of confounding or predicting total compensated time loss.

For the 6,502 eligible work-related injury events with linked claims (using **WTR-based** ICD-9-CM codes for scoring), there was substantial agreement between WTR and ICDMAP-90 classification of injuries into ISS categories (kappa=0.73), as well as between WTR and -icdpic- classification (kappa=0.68). There was almost perfect agreement between ICDMAP-90 and -icdpic- classification (kappa=0.89).

For the 4,301 eligible linked claims for which -icdpic- was able to estimate ISS from **WC-based** ICD-9-CM codes, there was moderate agreement between the WC-based ISS and the corresponding ISS contained in the WTR dataset (kappa=0.43). There was also moderate agreement between the WC-based ISS and the corresponding ISS estimated from WTR-based ICD-9-CM codes using -icdpic- (kappa=0.51).

Claims are closed when an injured worker is determined able to work, or to have TPD, or upon 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 (TL) as the time scale.[64] 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-[65] (based on the Fine and Gray semiparametric method[66]) 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.[67] For these analyses, proximate fatalities were excluded as our population of interest was injured workers who might return to work; later deaths were treated as a competing risk/censoring mechanism. Self-insured claims that met the inclusion criteria were included only for assessments of severity score concordance, due to unavailable outcomes data.

The Akaike Information Criterion (AIC)[68] allows for direct comparison of non-nested models with the same outcome variable and sample size. AIC rewards goodness of fit, penalizes increasing degrees of freedom, and estimates relative information content. Within each model set, we calculated delta AIC (ΔAIC) for each model by subtracting the AIC for the best model. The larger the ΔAIC, the more information was lost from that model relative to the best model (for which ΔAIC=0). ΔAIC of >10 indicates essentially no empirical support that a particular model may be the better model.[68] Differences in amount of variance explained (R^2) and estimated effects (SHR and OLS coefficients) were also compared (R^2 cannot be calculated for competing risk models).

We began by assessing prediction of work-related outcomes by WTR-based severity scores for the subset of WTR injuries that linked to a WC claim. We then estimated severity scores using WC billing data, regardless of whether the claim linked to a WTR injury report, to determine whether AIS-based severity scores could be useful using stand-alone WC data.

Assessment of WTR-based severity measures using linked WTR and WC claims data

Table 14 presents the observed outcome distribution for each of the four samples (we assessed these measures using an all-injury sample and also a TBI sample).

TABLE 14. Outcome status for each sample

Sample	Total N	Outcome status			
		TL ended without TPD	TPD	Died	Censored/claim still open
Work disability sample-all injuries	4,700	3,593 (76.5%)	355 (7.6%)	57 (1.2%)	695 (14.8%)
Work disability sample-TBI	932	593 (63.6%)	116 (12.5%)	9 (1.0%)	214 (23.0%)
Cost sample-all injuries	4,410	3,997 (90.6%)	355 (8.1%)	58 (1.3%)	n/a
Cost sample-TBI	802	675 (84.2%)	116 (14.5%)	11 (1.4%)	n/a

TL, time loss compensation.

As shown in **Figure 8**, there was a large monotonic increase in median time loss days to claim closure as injury severity increased. The most minor injuries had a median of just over two months of compensated time loss days, compared with several years for the most severe injuries.

FIGURE 8. Compensated time loss duration by injury severity level. An extra category (ISS: 1-3) was broken out to show the consistent trend (there were too few cases to do the same for TBI).

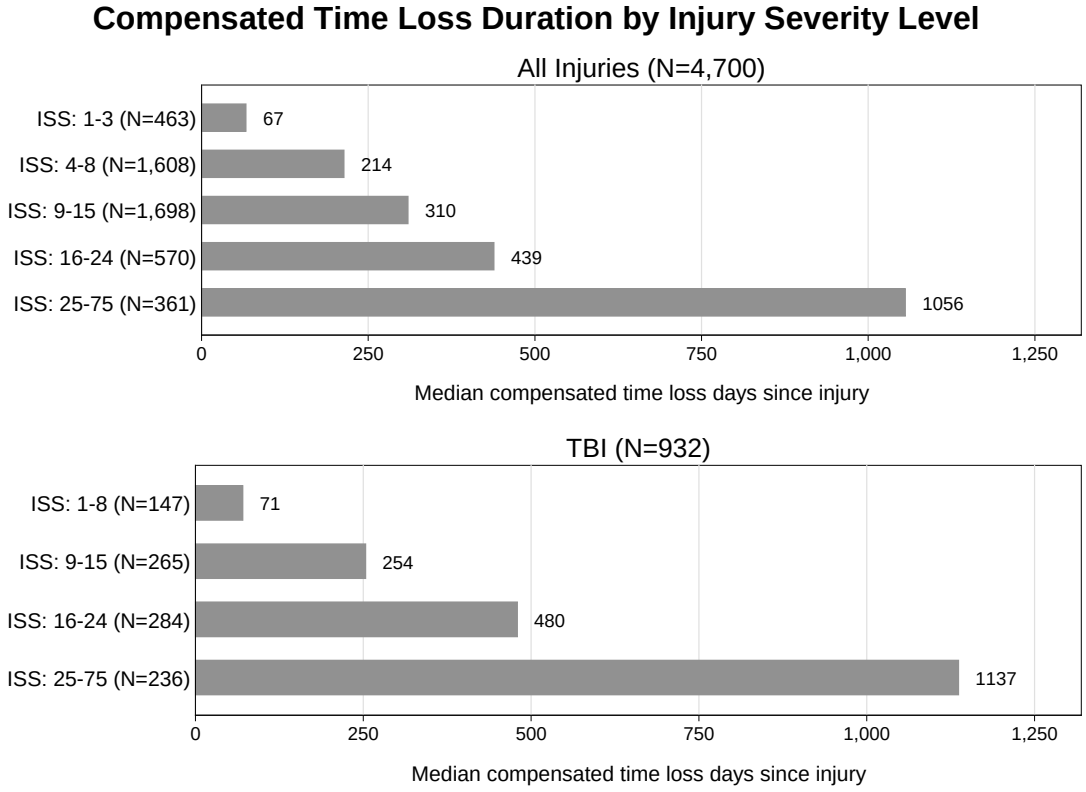


Table 15 presents the results of the competing risk models used to assess the effect of injury severity on work disability. All models were highly significant (p≤.00005 for all-injury models, p≤.0002 for TBI-only models). ΔAIC can be used either to compare models based on the type of injury severity score used within scoring method (vertically), or to compare models based on the scoring method used for one particular type of injury severity score (horizontally). The best model for each sample/outcome model set has ΔAIC=0. The distance from 0 indicates the amount of information lost relative to the best model within each model set, and absolute differences between other models within a model set are also informative.

Within score type, models using the WTR and ICDMAP-90 scoring methods consistently had lower AICs compared with -icdpic-. ISS and NISS tended to perform better in predicting the end of time loss without TPD, while maxAIS was a better predictor of TPD. The SHRs produced by all three scoring methods were very similar within score type. For example, on average, each 1 point increase in ISS was associated with a 4-5% decrease in the instantaneous probability of time loss ending without TPD, and a 3-4% increase in the instantaneous probability of TPD, regardless of scoring method or injury sample. The SHRs for ISS and NISS were similar for both outcomes in both samples. The SHRs for maxAIS cannot be directly compared to those for ISS and NISS, because the range of maxAIS was much narrower (there was a larger effect with each 1 point increase).

TABLE 15. Work disability outcomes, competing risks survival analysis

Sample/Outcome	Score type	Scoring method: WTR		ICDMAP-90		-icdpic-	
		SHR	Δ AIC	SHR	Δ AIC	SHR	Δ AIC
All injuries (N=4,700)							
1. TL ended without TPD							
	ISS	.957	53	.953	86	.955	113
	NISS	.965	**0**	.962	37	.963	63
	maxAIS	.697	88	.699	137	.700	157
2. TPD							
	ISS	1.040	16	1.043	14	1.036	34
	NISS	1.032	22	1.037	19	1.031	37
	maxAIS	1.634	5	1.687	**0**	1.582	22
TBI (N=932)							
3. TL ended without TPD							
	ISS	.952	**0**	.947	18	.948	30
	NISS	.964	2	.960	17	.962	24
	maxAIS	.643	33	.647	52	.640	62
4. TPD							
	ISS	1.031	10	1.037	5	1.028	15
	NISS	1.024	11	1.033	4	1.023	15
	maxAIS	1.506	9	1.711	**0**	1.502	13

The best model for each sample/outcome model set has Δ AIC=0 (bold). Δ AIC can be used either to compare models based on the type of injury severity score used within scoring method (vertically), or to compare models based on the scoring method used for one particular type of injury severity score (horizontally). SHR, subhazard ratio; AIC, Akaike Information Criterion; TL, time loss; ISS, Injury Severity Score, NISS, New Injury Severity Score, maxAIS, maximum Abbreviated Injury Scale (AIS) score over all 6 body regions.

As shown in **Figure 9**, there was a large monotonic increase in both median and mean adjusted total medical costs as injury severity increased.

FIGURE 9. Adjusted total medical costs by severity level.

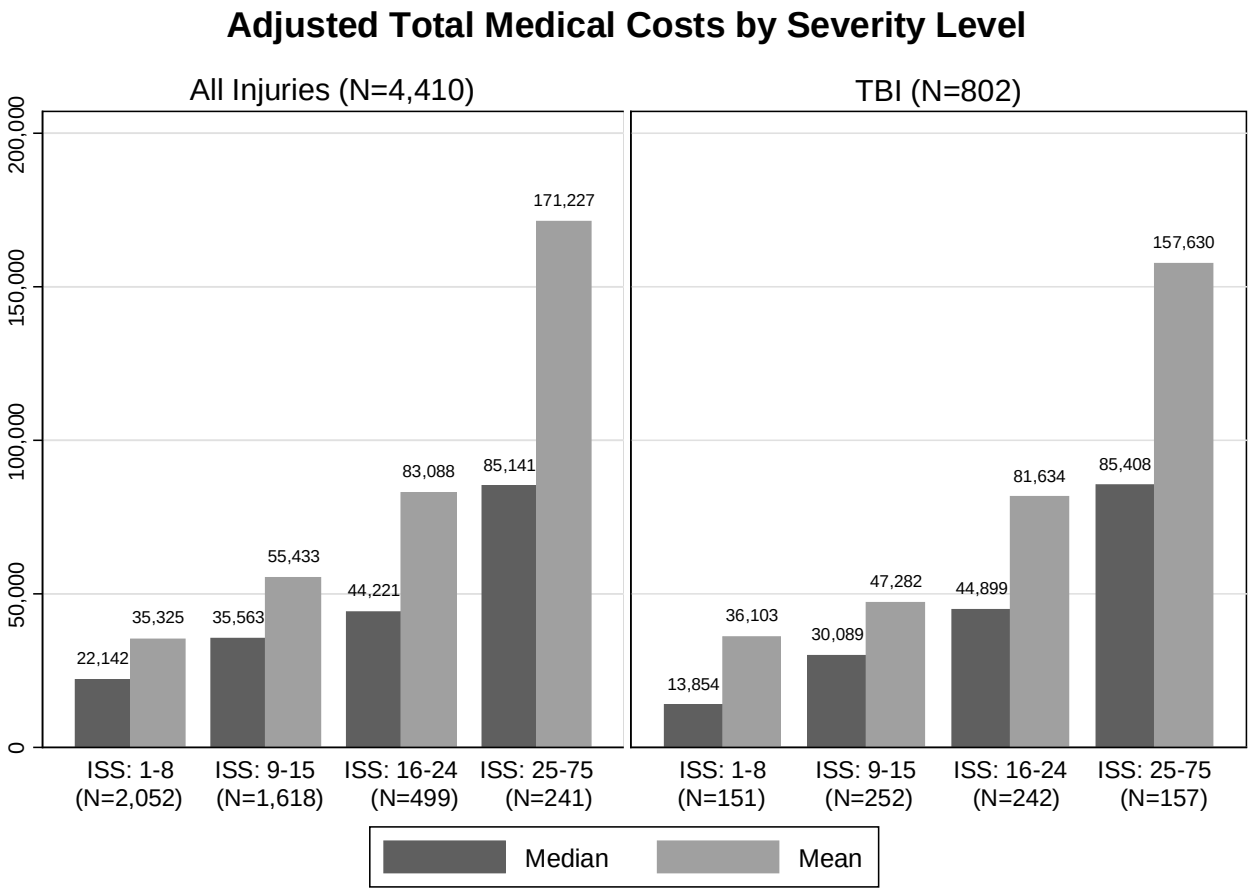


Table 16 presents the results of the OLS models used to assess the effect of injury severity on adjusted total medical costs. All models were highly significant (p≤.00005).

MaxAIS did not perform as well for predicting costs as did ISS and NISS, which were roughly comparable. The β coefficients produced by all three scoring methods were roughly similar within score type. For example, on average, each 1 point increase in ISS was associated with an increase of $4,300-$5,100 in adjusted total medical costs in the all-injury sample, depending on the scoring method (somewhat larger for the TBI sample). The β coefficients for maxAIS cannot be directly compared to those for ISS and NISS, because the range of maxAIS was narrower.

TABLE 16. Adjusted total medical costs in dollars

Sample	Score type	Scoring method: WTR β	WTR R^2	WTR Δ AIC	ICDMAP-90 β	ICDMAP-90 R^2	ICDMAP-90 Δ AIC	-icdpic- β	-icdpic- R^2	-icdpic- Δ AIC
1. All injuries (N=4,410)	ISS	4,304	.061	29	5,098	.067	**0**	4,490	.052	68
	NISS	3,304	.061	30	3,793	.064	15	3,320	.050	79
	maxAIS	31,367	.044	106	34,380	.047	91	32,253	.040	127
2. TBI (N=802)	ISS	4,675	.080	8	5,850	.089	**0**	5,071	.058	27
	NISS	3,621	.083	6	4,478	.090	**0**	3,632	.056	29
	maxAIS	45,734	.064	22	51,782	.068	18	40,613	.035	47

The best model(s) for each sample/outcome model set has Δ AIC=0 (bold). Δ AIC can be used either to compare models based on the type of injury severity score used within scoring method (vertically), or to compare models based on the scoring method used for one particular type of injury severity score (horizontally). Key: WTR, Washington State Trauma Registry; SHR, subhazard ratio; AIC, Akaike Information Criterion; ISS, Injury Severity Score, NISS, New Injury Severity Score, maxAIS, maximum Abbreviated Injury Scale (AIS) score over all 6 body regions; TBI, traumatic brain injury.

Assessment of severity measures estimated using the ICD-9-CM codes in WC billing data

We then estimated severity scores with -icdpic- using the ICD-9-CM codes from WC billing data for the first post-injury visit (facility and/or professional billing), regardless of whether the claim linked to a WTR injury report.

We assessed the association of injury severity with cost and work disability outcomes for all traumatic injuries combined and for three specific injury subsets: (1) amputations, (2) extremity fractures, and (3) traumatic brain injury (TBI). These injury samples were constructed separately for the cost sample and for the work disability sample, resulting in a total of eight samples. For the purposes of defining the injury sample and for injury severity scoring purposes, we used all ICD-9-CM codes from facility and professional billing data for the first medical encounter occurring within 30 days after the injury date. We used OIICS codes to define the primary/most severe injury for the injury subsets, and additionally required at least one relevant ICD-9-CM code for purposes of severity scoring (workers with multiple injuries were not excluded).

Injuries qualified for the all-injury sample if there was at least one ICD-9-CM diagnostic code for a traumatic injury as specified by the NTDB (800-904.9, 910-929.9, 950-957.9, 959-959.9); however, superficial injuries were not excluded due to their prevalence and relevance to occupational injury research.[40] Isolated burns were excluded for reasons explained earlier. Injuries qualified for the amputation subset when the first three digits of the OIICS nature of injury code were 031 (amputation with bone loss). Relevant ICD-9-CM codes for amputations were 885-887 and 895-897. Injuries qualified for the extremity fracture subset when the first three digits of the OIICS nature of injury code were 012 (fracture) and either the first two digits of the OIICS part of body code were 21 (shoulder) or the first digit was 3 (upper extremities) or 4 (lower extremities). Relevant ICD-9-CM codes for extremity fractures (including clavicle and scapula fractures) were 810-829. Injuries qualified for the TBI subset when either: (1) the first two digits of the OIICS nature of injury code were 06 (intracranial) or (2) the first three digits of the OIICS nature of injury code were 012 (fracture) in combination with the first two digits of the

OIICS part of body code being 01 (cranial region). We followed the CDC case definition with respect to the relevant ICD-9-CM codes for TBI: 800.0-801.9, 803.0-804.9, 850.0-854.1, 950.1-950.3, or 959.01.[30] TBI was problematic to identify using OIICS; there is no accepted OIICS-based definition,[62] and it was also clear from our data that this set of OIICS codes were quite insensitive for identifying nonfatal TBI. However, for purposes of this paper, we needed a specific rather than sensitive definition.

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 included ISS and/or early hospitalization. No cases had missing age data. There was one case with missing gender (present in both all-injury samples, but not included in an injury subsamples) and was therefore dropped from the all-injury regression models. Rural injuries (used solely for an illustration of confounding by injury severity) were defined as those occurring in rural counties using 2009 Washington State Office of Financial Management guidelines.[69]

In **Table 17**, we present information on the feasibility and coverage of estimating AIS-based injury severity scores from the ICD-9-CM codes available in WC medical billing data. For several denominators based solely on OIICS criteria, we calculated the number and percent of claims for which ICD-9-CM codes were available and/or for which -icdpic- was able to estimate ISS. ISS could be estimated for 67% of all compensable nonfatal State Fund claims regardless of the nature of injury or illness, for 80% of all OIICS-defined traumatic injuries, and for over 90% of amputations and extremity fractures.

Table 17 also presents the number and percent of claims linking to the WTR using the same denominators. Overall, fewer than 2% of injuries linked to the WTR due to the relatively minor nature of most work-related injuries; however, more than a quarter of non-fingertip amputations were linked. Progressively more severe injury types were linked at higher rates (data not shown); for example, among all amputations, 65% of those observed to result in TPD were linked to the WTR. However, even the most severe and disabling injuries were not always linked to the WTR, in part due to trauma treated at non-reporting hospitals, out-of-state injuries, and factors other than anatomic injury severity that can result in TPD.

TABLE 17. Percent of claims that were severity scored and/or linked to WTR injuries

Denominator/Injury type	N	Claim had ICD-9-CM codes available		Injury severity was scored by -icdpic-		Claim linked to WTR[a]	
		N	%	N	%	N	%
All compensable State Fund claims	347,184	304,201	87.6	231,661	66.7	5,477	1.6
All traumatic injuries[a]	269,153	242,095	90.0	216,386	80.4	4,772	1.8
Amputations[a]	2,180	2,014	92.4	2,001	91.8	227	10.4
Non-fingertip amputations[a]	237	219	92.4	217	91.6	63	26.6
Extremity fractures[a]	26,168	24,117	92.2	23,683	90.5	1,407	5.4

[a] Defined using OIICS criteria but not ICD-9-CM criteria.

Table 18 presents ISS distribution by injury type as well as the number of injuries in each of the eight samples constructed for the outcome analyses. These eight samples were defined by injury type (using a combination of OIICS and ICD-9-CM codes) and outcome (cost or work disability).

TABLE 18. Number of injured workers and injury severity distribution for each injury/outcome sample

Injury type	Work disability sample	Cost sample	Claims in either sample	Percent of claims in each ISS category				
				1-3	4-8	9-15	16-24	25-75
All injuries[a]	191,820	200,800	208,522	66.95	29.66	2.74	.44	.21
Amputations[a]	1,645	1,799	1,839	0	94.78	4.89	.22	.11
Extremity fractures[a]	19,706	21,202	21,825	22.64	70.25	6.69	.28	.13
TBI[a]	889	923	995	1.91	80.00	11.16	5.93	1.01

[a] Defined by the corresponding OIICS-based primary injury codes as well as at least one relevant ICD-9-CM code.

As shown in **Table 19**, there was a large monotonic increase in both median and mean adjusted total medical costs as injury severity increased, for all four injury samples.

TABLE 19. Descriptive summary of adjusted total medical costs (dollars)

Sample/Severity level	N	Total for life of claim (closed claims only)				
		Mean	SE	25th percentile	Median	75th percentile
All injuries						
ISS: 1-3	134,787	12,987	73	1,085	3,330	13,093
ISS: 4-8	59,593	16,007	126	2,240	6,880	17,679
ISS: 9-15	5,307	38,462	888	5,023	18,779	46,336
ISS: 16-24	769	91,021	5,479	18,994	47,101	111,166
ISS: 25-75	344	181,925	28,826	14,099	66,038	163,302
All severity levels	200,800	15,145	88	1,380	4,409	15,627
Amputations						
ISS: 1-8	1,716	16,479	686	4,266	8,105	15,746
ISS: 9-75	83	119,384	14,761	22,817	72,459	165,790
All severity levels	1,799	21,227	1,070	4,494	8,428	17,411
Extremity fractures						
ISS: 1-3	4,917	6,759	159	1,319	2,646	8,352
ISS: 4-8	14,863	16,654	230	2,382	7,214	19,644
ISS: 9-15	1,349	48,240	1,588	14,516	30,343	61,792
ISS: 16-75	73	193,750	87,112	33,451	71,496	153,576
All severity levels	21,202	16,978	368	2,091	6,309	18,673
TBI						
ISS: 1-8	765	14,989	1,044	1,802	4,254	12,591
ISS: 9-15	99	47,436	8,257	11,118	21,085	48,563
ISS: 16-75	59	99,023	28,349	17,357	36,218	82,979
All severity levels	923	23,841	2,299	2,144	5,681	20,122

Table 20 presents the results of the OLS models used to assess the effect of injury severity on adjusted total medical costs. All models that included a severity measure were highly significant (p≤.0001). Δ AIC can be compared only within each injury sample (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 model set, and absolute differences between other models within a model set are also informative. Early hospitalization contributed more information to the all-injury sample than did ISS, based on both Δ AIC and R^2. The reverse was true for all three injury subsamples, with ISS contributing more information than early hospitalization. In all cases, using both measures resulted in the most informative models.

TABLE 20. Comparison of severity indicators using adjusted total medical cost outcome

Model	All injuries (N=200,799)		Amputations (N=1,799)		Extremity fractures (N=21,202)		TBI (N=923)	
	R^2	Δ AIC	R^2	Δ AIC	R^2	Δ AIC	R^2	Δ AIC
Reference (age/gender only)	.007	25499	.004	551	.002	2203	.021	107
ISS	.063	13709	.228	94	.069	735	.108	25
Early hospitalization	.086	8788	.090	391	.055	1057	.083	49
Early hospitalization & ISS	.125	**0**	.268	**0**	.101	**0**	.134	**0**

All models include age and gender. ΔAIC can be compared only within each injury sample (vertically). The best model for each model set has ΔAIC=0 (bold). ISS categories vary by injury sample as shown in Table 19.

Table 21 presents the observed outcome distribution for all four injury samples, by injury severity.

TABLE 21. Outcome status and censoring by injury severity (work disability samples)

Severity level	Total N	Outcome status			
		Time loss ended without TPD	TPD	Died	Censored/claim still open
All injuries					
ISS: 1-3	129,025	121,563 (94.2%)	2,022 (1.6%)	622 (0.5%)	4,818 (3.7%)
ISS: 4-8	56,433	52,926 (93.8%)	927 (1.6%)	324 (0.6%)	2,256 (4.0%)
ISS: 9-15	5,139	4,475 (87.1%)	210 (4.1%)	50 (1.0%)	404 (7.9%)
ISS: 16-24	816	587 (71.9%)	77 (9.4%)	6 (0.7%)	146 (17.9%)
ISS: 25-75	407	264 (64.9%)	53 (13.0%)	4 (1.0%)	86 (21.1%)
All severity levels	191,820	179,815 (93.7%)	3,289 (1.7%)	1,006 (0.5%)	7,710 (4.0%)
Amputations					
ISS: 1-8	1,556	1,515 (97.4%)	8 (0.5%)	S	S
ISS: 9-75	89	63 (70.8%)	11 (12.4%)	S	S
All severity levels	1,645	1,578 (95.9%)	19 (1.2%)	8 (0.5%)	40 (2.4%)
Extremity fractures					
ISS: 1-3	4,436	4,392 (99.0%)	10 (0.2%)	S	S
ISS: 4-8	13,857	13,127 (94.7%)	187 (1.4%)	S	S
ISS: 9-15	1,329	1,163 (87.5%)	46 (3.5%)	S	S
ISS: 16-75	84	55 (65.5%)	11 (13.1%)	S	S
All severity levels	19,706	18,737 (95.1%)	254 (1.3%)	93 (0.5%)	622 (3.2%)
TBI[c]					
ISS: 1-8	731	652 (89.2%)	25 (3.4%)	S	S
ISS: 9-15	98	78 (79.6%)	8 (8.2%)	S	S
ISS: 16-75	60	43 (71.7%)	7 (11.7%)	S	S
All severity levels	889	773 (87.0%)	40 (4.5%)	4 (0.5%)	72 (8.1%)

S=Suppressed due to several very small cell sizes.

As shown in **Table 22**, there was a large monotonic increase in median time loss days to claim closure as injury severity increased for all four injury samples.

TABLE 22. Compensated time loss duration by injury severity (work disability samples)

Sample/Severity level	N	Median	95% CI
All injuries			
ISS: 1-3	129,025	21	21-22
ISS: 4-8	56,433	40	39-41
ISS: 9-15	5,139	91	85-96
ISS: 16-24	816	250	210-341
ISS: 25-75	407	406	276-607
All severity levels	191,820	27	27-28
Amputations			
ISS: 1-8	1,556	32	29-35
ISS: 9-75	89	433	234-728
All severity levels	1,645	34	31-38
Extremity fractures			
ISS: 1-3	4,436	18	17-20
ISS: 4-8	13,857	61	59-62
ISS: 9-15	1,329	162	145-179
ISS: 16-75	84	394	322-839
All severity levels	19,706	51	50-53
TBI			
ISS: 1-8	731	18	14-23
ISS: 9-15	98	83	48-154
ISS: 16-75	60	128	67-366
All severity levels	889	26	22-32

Figure 10 presents a series of stacked cumulative incidence plots that display the estimated relative probability of each outcome over time for the all-injury work disability sample by injury severity.[65] The probability of each outcome grows as open claims shrink over time. The cumulative incidence of TPD was notably larger for major compared with minor injuries. Minor injuries had a more convex curve for time loss ending without TPD, indicating more rapid resolution of the claim. The cumulative incidence of death was very small with little increase over time.

FIGURE 10. Stacked cumulative incidence of outcome events by injury severity level (N=191,820). The cumulative incidence (probability) of each of the competing outcomes (including censored status) sums to 1 at every point in time.

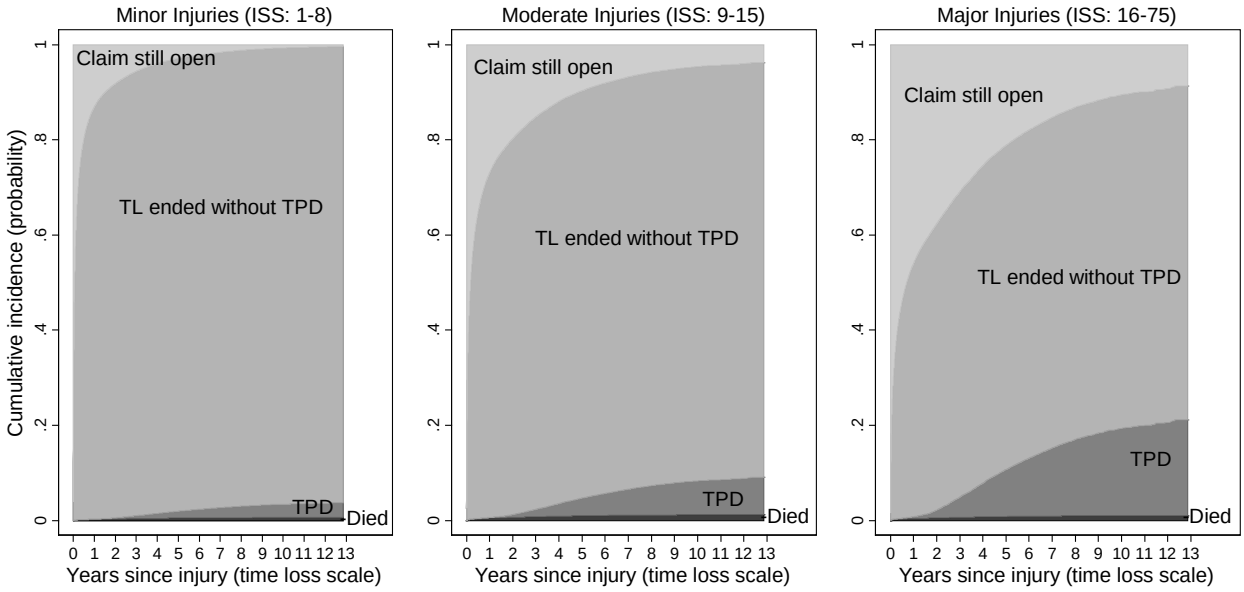


Table 23 presents the results of the competing risk survival analysis models used to assess the effect of injury severity on work disability. All models that included ISS and/or early hospitalization were more informative than those including just age and gender. For the end of time loss outcome, early hospitalization contributed more information to all of the injury samples except amputations than did ISS. The reverse was true for amputations, with ISS contributing more information than early hospitalization. In all cases, using both measures resulted in the most informative models. There is a less consistent pattern for the TPD outcome. For amputations, ISS alone had a lower AIC than both ISS and early hospitalization together (but with a Δ AIC of only 2, there is substantial evidence that the combined model may be the most informative). For TBI, early hospitalization alone had the lowest AIC (but again, the Δ AIC was only 3 for the combined model). For both the all-injury sample and extremity fractures, including both ISS and early hospitalization together were most informative.

TABLE 23. Comparison of severity indicators using work disability outcomes, competing risk models

Model	All injuries (N=191,819)	Amputations (N=1,645)	Extremity fractures (N=19,706)	TBI (N=889)
	Δ AIC	Δ AIC	Δ AIC	Δ AIC
Time loss ended without TPD				
Reference (age/gender only)	20993	190	3767	127
ISS	18190	56	1513	96
Early hospitalization	706	88	1387	1
Early hospitalization & ISS	**0**	**0**	**0**	**0**
TPD				
Reference (age/gender only)	2196	42	206	22
ISS	1841	**0**	103	20
Early hospitalization	133	36	51	**0**
Early hospitalization & ISS	**0**	2	**0**	3

All models include age and gender. Δ AIC can be compared only within each injury sample (vertically). The best model for each model set has Δ AIC=0 (bold). ISS categories vary by injury sample as shown in Table 22.

Table 24 presents trends in effect sizes by injury severity for each of the three outcomes for all four injury samples. For example, workers with the most severe extremity fractures had $186,372 higher adjusted total medical costs on average than those with the most minor extremity fractures. Workers with major TBI were half as likely to end time loss compensation (without TPD determination or death) at any given time compared with those with minor TBI. Severe amputations (e.g., above the knee) were roughly 34 times as likely to result in a TPD determination as were minor amputations, such as a finger or thumb (though significant, the confidence interval was quite wide). These were overly parsimonious models and these estimates are provided just as examples; observed effect sizes will vary depending on details of the sample, setting, covariates, outcome definitions, etc. There was no significant difference between ISS 1-3 and ISS 4-8 for the TPD outcome using the all-injury sample; TPD was equally rare in both categories (see **Table 21**). There was also no significant difference between major TBI and either moderate or minor TBI with respect to the TPD outcome, but both moderate and major TPD involved very few instances of observed TPD; perhaps too few to allow for discrimination. Aside from those two anomalies, there was a monotonic trend by injury severity in the expected direction for every injury sample and every outcome. Although each individual ISS category was not always significantly different from the adjacent category, ISS categories were always jointly significant ($p<.00005$ for all models, except $p=.03$ for the TBI sample/TPD outcome model).

TABLE 24. Trends in effect sizes by injury severity for medical cost and work disability outcomes

Model	Total medical costs (dollars)		TL ended without TPD		TPD	
	β	95% CI	SHR	95% CI	SHR	95% CI
All injuries						
ISS: 1-3	0	reference	1	reference	1	reference
ISS: 4-8	2,913	2,628-3,199	.880	.871-.888	0.93	0.86-1.001
ISS: 9-15	25,520	23,775-27,264	.607	.591-.624	2.18	1.89-2.52
ISS: 16-24	78,083	67,362-88,803	.373	.346-.401	5.39	4.27-6.81
ISS: 25-75	169,245	112,819-225,670	.315	.282-.352	8.38	6.35-11.05
Amputations						
ISS: 1-8	0	reference	1	reference	1	reference
ISS: 9-75	102,695	73,814-131,577	.282	.223-.356	34.42	11.56-102.54
Extremity fractures						
ISS: 1-3	0	reference	1	reference	1	reference
ISS: 4-8	9,890	9,302-10,478	.472	.453-.491	5.29	2.80-9.99
ISS: 9-15	41,331	38,206-44,456	.273	.257-.291	12.83	6.47-25.45
ISS: 16-75	186,372	16,701-356,042	.154	.121-.197	50.15	21.38-117.64
TBI						
ISS: 1-8	0	reference	1	reference	1	reference
ISS: 9-15	30,121	13,115-47,127	.611	.493-.756	2.44	1.12-5.32
ISS: 16-75	81,181	24,592-137,770	.510	.386-.673	2.34	.87-6.27

All models include only age, gender, and the ISS categories listed.

This study demonstrated the feasibility of estimating ISS for most traumatic injury claims using medical billing data and also demonstrated that ISS was significantly associated with work disability and medical cost outcomes. Work disability and medical costs consistently increased monotonically with injury severity for almost all injury samples and outcomes. There were two exceptions, both involving the TPD outcome. ISS appeared less strongly predictive of TPD (but not time loss ending without TPD) specifically for the TBI sample. It is not clear why this would be the case; perhaps due to particularities of the case definition we used or perhaps the relationship between TBI and TPD is differentially more dependent on factors other than injury severity compared with other injury types. It is perhaps more surprising that ISS did have a measurable effect on TPD for all four injury samples, given the complexity of factors leading to TPD as well as the length of time usually involved in arriving at a TPD determination.[70] The median observed time to TPD determination was 3.9 years (measured in compensated time loss days), without significant variation by ISS. Previous studies have suggested that ISS is less strongly associated with longer-term compared with shorter-term work disability outcomes.[71,72]

Although each individual ISS category was not always significantly different from the adjacent category, each set of ISS categories was always jointly significant overall. These categories could be further collapsed depending on research goals, however more complete adjustment for confounding may be obtained by retaining as many of these categories as feasible, assuming a large enough sample to support the necessary degrees of freedom. For purposes of illustrating the potential for confounding by injury severity, let's imagine that we are interested in the effect of an injury occurring in a rural (compared with urban) area on outcomes. Rural injuries were positively associated with higher injury severity as well as higher medical costs and more lost work days in this data set. Using the all-injury sample and including age, gender, and the rural indicator in a linear regression model, the rural coefficient for adjusted total medical costs was $1,104 (95% CI: $762, $1,447). Adding the set of ISS categories to the model resulted in a rural

coefficient of $638 (95% CI: $293, $984), a 42% reduction in magnitude. A similar but smaller reduction occurred for the comparable time loss model; rural injuries were estimated to be 8.0% less likely to have time loss end at any given time assuming TPD or death does not occur, compared with non-rural injuries (95% CI: 7.1%, 8.9%). After the set of ISS categories was added to the model, the estimate shrunk 12.5% to become 7.0% less likely (95% CI: 6.0%, 7.9%).

An indicator of early hospitalization was often at least as good a predictor of work disability and cost outcomes as was ISS and may be simpler to construct. Although using ISS together with an early hospitalization indicator usually resulted in the most informative models, there may be reasons to avoid the use of one or the other in particular circumstances. In addition to being a proxy for higher severity, 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). It has been pointed out that length of stay, and by extension, inpatient hospitalization, is subject to a number of influences other than severity or medical need, due to changes in standards of care and service delivery over time.[73] In contrast, AIS-based injury severity scoring is theoretically appealing, since it estimates baseline anatomic injury severity. ISS provides the benefit of further severity discrimination for injuries that don't involve hospitalization, or between injuries that do. The fact that ISS cannot always be calculated or may not be appropriate for every type of injury may present a significant barrier for some studies. There are alternative validated severity measures for certain specific injuries which focus on the unique issues and functional challenges associated with the particular body part or mechanism (e.g., Hand Injury Severity Score for hand trauma,[74] Abbreviated Burn Severity Index for burns[75]). 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,[76] which can also be estimated from ICD-9-CM codes using -icdpic- or Stata's -charlson- program).

There was moderate agreement between WC-based and WTR-based estimates of injury severity (kappa=0.43, or 0.51 when ISS for both was estimated using -icdpic-). This may in part be due to the differing purposes of these data across data sets. The WTR-based ICD-9-CM codes and injury severity estimates were generated for clinical descriptive purposes, while the ICD-9-CM codes in the L&I billing data were generated solely for billing purposes. Although it is true that WTR scores may be based on informed and careful decisions made by trauma surgeons and trauma registrars, it is also true that the trauma registrars have quite variable levels of training and experience. Therefore, this comparison provides us with an idea of the amount of concordance with the existing and accepted WTR-based ISS, rather than with a gold standard. It is possible that the quality and completeness of the ICD-9-CM codes available in WC billing data are inferior to those available in the WTR and that those characteristics vary greatly by facility/provider. It is not possible to distinguish codes present for diagnostic ("rule-out") purposes from those that indicate definitive diagnoses. Fee schedules may affect how ICD-9-CM codes are entered by billing specialists, which could also vary by facility/provider type.

In the only previous evaluation of -icdpic- that we were able to identify, Di Bartolomeo et al. concluded that -icdpic- agreed poorly with scores estimated by expert trauma registrars.[77] However, the study was conducted using a small sample (N=272) from the Italian Trauma Registry, which, as the authors noted, differs in several important respects from U.S.-based trauma registries. -icdpic-'s underlying tables that crosswalk from ICD-9-CM codes to AIS severity and body region are modifiable by the user. Due to the empirical methodology used to construct these tables, they may benefit from a thorough review by an AIS-trained clinical

trauma specialist to determine whether any particular mapping might merit adjustment. ICDMAP-90 is another existing software package that can be used to estimate AIS-based injury severity. Although ICDMAP-90 has some advantages, it is not current to the most recent ICD-9-CM and AIS changes and does not run on newer computers. However, it does estimate ISS for burns (though those scores may be overly conservative). We found that ISS estimated by ICDMAP-90 from WC ICD9 codes had slightly higher concordance with WTR-based scores than those estimated by -icdpic-, but remained within the "moderate agreement" range (kappa=0.51). In preliminary head-to-head comparisons of ICDMAP-90 with -icdpic-, we have found that ICDMAP-90 has only a slight advantage over -icdpic- for prediction of work-related outcomes. We used -icdpic- for this study because -icdpic- may be more accessible to most researchers; it is freely available to Stata users, runs on modern computers, is updated periodically, and has an intuitive interface. ICD-9-CM codes are still in use in the U.S., where this study was based. Jurisdictions that have transitioned to ICD-10 will not be able to use ICDMAP-90 or -icdpic- in their present forms to estimate AIS-based injury severity.

Other injury severity scoring systems have been proposed. For example, the New Injury Severity Score (NISS) has sometimes been found more predictive of injury mortality than ISS, particularly for penetrating injuries.[34,35] NISS is calculated similarly to ISS, but is based on the three highest AIS scores, regardless of body region. However, in preliminary work, we found little difference between ISS and NISS with regard to predicting work-related outcomes. Another injury severity measure which has been shown to out-perform ISS, the International Classification of Disease Injury Severity Score (ICISS), is based on empirically derived survival risk ratios.[78] This type of score is not likely to be as useful for the purposes we are contemplating because it is derived from injury mortality as an observable and measurable outcome; whereas we are most interested in outcomes for injury survivors. Estimation of ICISS for every ICD-9-CM code requires a sufficiently large generalizable sample. Previously promulgated ICISS estimates are generally based on predicting hospital survival conditional on hospital admission and lack the independent descriptive value of AIS-based severity.[79,80]

Although commonly used in trauma research, AIS-based injury severity measures have rarely been used in occupational injury research. However, there are potentially a variety of novel and important applications for occupational injury research and surveillance, including risk adjustment for program evaluation, intervention, or outcome studies, or severity restriction when constructing comparison groups or case definitions for surveillance. We conducted this study as an effort toward addressing the clear need for better severity measures for occupational health services research.[81] This study demonstrated that AIS-based injury severity measures were significantly associated with work disability and medical cost outcomes for work-related injuries. Although there were clear differences in model fit and information content, there was little practical difference between the various WTR-based injury severity scores and ICDMAP-90 or -icdpic- estimates of the effect of injury severity on these outcomes. Our findings provide some reassurance regarding the use of either ICDMAP-90 or -icdpic- software to derive scores directly from ICD-9-CM codes in non-trauma registry data sets.

2d. After conducting the above analyses, meet with L&I research staff to share findings and discuss whether and how L&I research might be enhanced by the addition of measures available in the WTR but not in L&I claims data (e.g., measures of baseline severity, pre-existing conditions, race/ethnicity).

This aim was met via several in-person meetings and ongoing email and telephone communication with L&I staff over the course of this project.

Specific Aim 3: *Explore and document the extent of under-representation of work-related traumatic injuries in L&I claims data and the potential of the WTR to contribute to case ascertainment. Evaluate whether there are trends in under-representation over time, overall and by severity and race/ethnicity.*

3a. *Describe the number and proportion of work-related traumatic injuries captured by the WTR that do not have an associated L&I WC claim.*
3b. *Evaluate whether under-representation varies by severity and/or race/ethnicity.*
3c. *Evaluate whether there are trends in under-representation rates over time.*

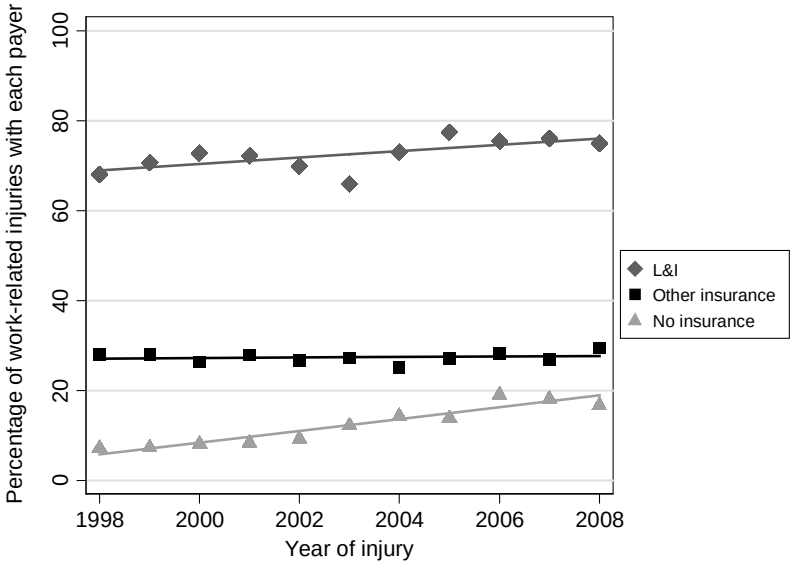
Specific Aim 4: *Describe the distribution of payers and evaluate trends in payer coverage for work-related traumatic injuries captured by the WTR, overall and by severity and race/ethnicity.*

4a. *Of all work-related trauma in the WTR, calculate the proportion covered by each payer category.*
4b. *Evaluate whether these proportions vary by severity and/or race/ethnicity.*
4c. *Evaluate whether these proportions change over time.*

Results for Aims 3 and 4 are complementary and are presented together.

Of 9,185 work-related injury events reported to the WTR (for 9,134 individual workers), 5,805 injury events (63.2%) were linked to a compensable WC claim (for 5,780 individual workers). The percentage of all 9,185 work-related injury events with L&I listed as a payer was 72.6% on average for all 11 years, and as shown in **Figure 11**, gradually increased over time (p=.02). The percentage with no insurance was 12.9% on average for all 11 years, and increased more markedly over time (p<.0005). In contrast, the percentage with other insurance was stable at 28.2% (trend test not significant). These are non-exclusive categories (there are two payer fields), so percentages sum to more than 100%. (3.1% of work-related injury events had no payer information available and were not assumed to have no insurance.)

FIGURE 11. Trends in payer distribution. Payer categories are not mutually exclusive.



As shown in **Table 25**, workers with more severe work-related injuries were significantly more likely to have other insurance listed as a payer (alone or in addition to L&I), and less likely to have L&I alone listed as a payer. Latinos were significantly more likely to have L&I as a listed payer and much less likely to have other insurance, compared with non-Latinos.

TABLE 25. Payer distribution (percentages) for work-related traumatic injuries reported to the WTR by injury severity and ethnicity.

		Injury Severity Score*			Ethnicity*	
Payer category[a]	Overall (N=9,185)	Minor (N=4,133)	Moderate (N=3,195)	Major (N=1,814)	Non-Latino (N=5,821)	Latino (N=1,225)
L&I only	65.2	67.1	65.2	60.6	62.5	78.6
L&I and other insurance	7.4	6.6	7.8	8.6	7.8	5.5
Other insurance only	20.0	18.1	20.8	22.9	22.0	7.8
No insurance	4.4	4.5	4.2	4.6	4.2	5.0
No payer information	3.1	3.7	2.1	3.3	3.5	3.2

[a] Payer categories are mutually exclusive.
*p<.0005 (Pearson's Chi^2 test of independence).

As depicted in **Figure 12**, the overall percentage of work-related injuries reported to the WTR that had an associated compensable WC claim rose slightly over time (p<.0005). There was no significant trend in linkage to a WC claim when L&I was listed as a payer. However, injured workers with no insurance coverage (p=0.048), and, to an even greater extent, injured workers with other insurance (p<.0005) were increasingly likely over time to have a compensable WC claim. **Table 26** lists the numbers and percentages of work-related injuries that were linked to a compensable WC claim by year and payer. Among workers with L&I listed as an expected payer, workers who also had other insurance coverage had nearly twice the odds of having no linked WC claim (OR: 1.89, 95% CI: 1.57, 2.26), with no significant interaction by ethnicity.

FIGURE 12. Linkage to workers' compensation (WC) claims for work-related traumatic injuries, by year and payer. Payer categories are not mutually exclusive.

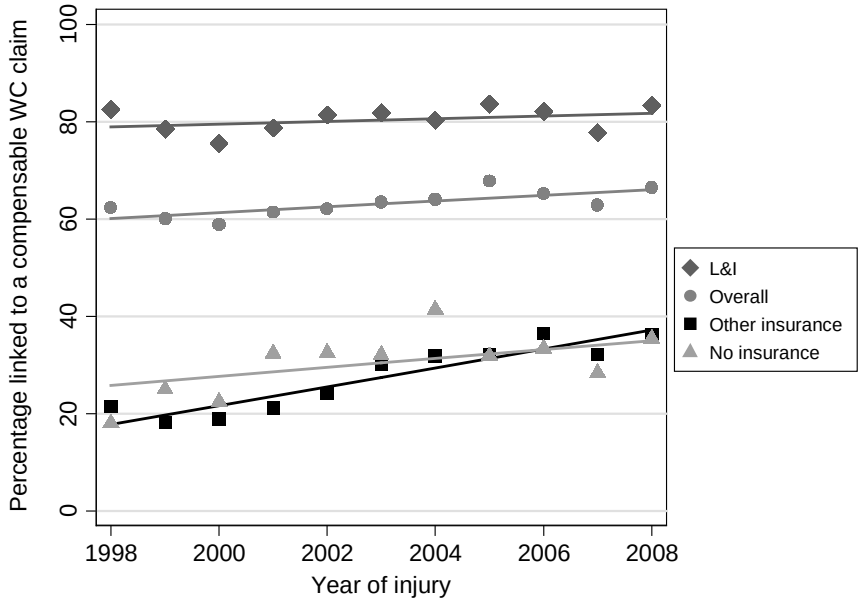


TABLE 26. Linkage to workers' compensation claims for work-related traumatic injuries reported to the WTR by year and payer, 1998-2008

	Overall		By payer[a]					
			L&I		Other insurance		No insurance	
Year	N	% linked	N	% linked	N	% linked	N	% linked
All years	9,185	63.2	6,665	80.5	2,511	27.9	1,148	31.5
1998	698	62.3	475	82.5	195	21.5	50	18.0
1999	770	60.1	544	78.5	216	18.1	56	25.0
2000	823	58.8	599	75.5	217	18.9	67	22.4
2001	813	61.4	587	78.7	227	21.2	68	32.4
2002	838	62.1	585	81.4	224	24.1	77	32.5
2003	819	63.5	540	81.9	223	30.0	100	32.0
2004	815	64.1	595	80.3	204	31.9	116	41.4
2005	818	67.7	633	83.6	221	32.1	113	31.9
2006	932	65.2	703	82.1	263	36.5	177	33.3
2007	995	62.9	756	77.8	267	32.2	180	28.3
2008	864	66.4	648	83.3	254	36.2	144	35.4
Trend test		<.0005		.072		<.0005		.048

[a] Payer categories are not mutually exclusive.

Table 27 presents characteristics of injured workers and their injuries, overall and by whether they had a compensable WC claim. Injured workers without a linked compensable WC claim tended to be older (42.7 years compared with 39.6 years, p<.00005), more likely to have insurance other than L&I, and less likely to have an amputation but more likely to have TBI.

TABLE 27. Work-related injuries reported to the WTR, 1998-2008

	Total (N=9,185)		Unlinked (N=3,380)		Linked (N=5,805)		
Characteristic[a]	N	%	N	%	N	%	P-value for difference
Gender							NS
Male	8,086	88.0	2,989	88.4	5,097	87.8	
Female	1,098	12.0	391	11.6	707	12.2	
Age							<.0005
16-24	1,351	14.7	433	12.8	918	15.8	
25-34	2,002	21.8	676	20.0	1,326	22.8	
35-44	2,221	24.2	780	23.1	1,441	24.8	
45-54	2,064	22.5	774	22.9	1,290	22.2	
55-64	1,125	12.3	461	13.6	664	11.4	
65 and older	422	4.6	256	7.6	166	2.9	
Race/ethnicity							<.0005
White	6,092	66.3	2,359	69.8	3,733	64.3	
Latino/Hispanic (any race)	1,225	13.3	281	8.3	944	16.3	
Black/African-American	196	2.1	64	1.9	132	2.3	
Asian/Pacific Islander	221	2.4	91	2.7	130	2.2	
Native American	65	0.7	54	1.6	11	0.2	
Other	128	1.4	51	1.5	77	1.3	
Unknown/Missing	1,258	13.7	480	14.2	778	13.7	

Characteristic[a]	Total N	Total %	Unlinked N	Unlinked %	Linked N	Linked %	P-value
Payer							<.0005
L&I only	5,987	65.2	1,100	32.5	4,887	84.2	
L&I and other insurance	678	7.4	202	6.0	476	8.2	
Other insurance only	1,833	20.0	1,608	47.6	225	3.9	
No insurance	406	4.4	355	10.5	51	0.9	
No payer information	281	3.1	115	3.4	166	2.9	
Injury Severity Score							NS
Minor (1-8)	4,133	45.2	1,493	44.5	2,640	45.6	
Moderate (9-15)	3,195	35.0	1,167	34.8	2,028	35.1	
Major (16-75)	1,814	19.8	696	20.7	1,118	19.3	
Injury involved an amputation	587	6.4	149	4.4	438	7.6	<.0005
Traumatic brain injury	1,910	20.8	762	22.5	1,148	19.8	.002
Fatality (DOA or in-hospital)	247	2.7	101	3.0	146	2.5	NS
Cause of injury							<.0005
Motor vehicle traffic	838	9.1	375	11.1	463	8.0	
Pedestrian, other	66	0.7	24	0.7	42	0.7	
Transport, other	382	4.2	226	6.7	156	2.7	
Firearm	78	0.9	42	1.2	36	0.6	
Falls	3,510	38.2	1,277	37.8	2,233	38.5	
Fire/burn	468	5.1	162	4.8	306	5.3	
Cut/pierce	478	5.2	175	5.2	303	5.2	
Struck by/against	1,195	13.0	464	13.7	731	12.6	
Machinery	1,225	13.3	290	8.6	935	16.1	
Natural/environmental	83	0.9	44	1.3	39	0.7	
Overexertion	68	0.7	30	0.9	38	0.7	
Other specified	737	8.0	244	7.2	493	8.5	
Other specified, NEC	27	0.3	14	0.4	13	0.2	
Unspecified/missing	30	0.3	13	0.4	17	0.3	
Place of injury							<.0005
Home	524	5.7	327	9.7	197	3.4	
Farm	456	5.0	198	5.9	258	4.4	
Mine/quarry	27	0.3	5	0.2	22	0.4	
Industrial	5,040	54.9	1,393	41.2	3,647	62.8	
Sports/recreation	153	1.7	99	2.9	54	0.9	
Street/highway	883	9.6	396	11.7	487	8.4	
Public building	361	3.9	112	3.3	249	4.3	
Residential institution	101	1.1	59	1.8	42	0.7	
Other specified	904	9.8	461	13.6	443	7.6	
Unspecified/missing	736	8.0	330	9.8	406	7.0	

NS, not statistically significant; DOA, dead on arrival; NEC, not elsewhere classifiable.
[a] Categories for some characteristics do not sum to 9,185 due to missing data.

In the subset not missing ethnicity or payer information, 13.7% of Latinos had insurance other than L&I listed as a payer, compared with 30.9% of non-Latinos (N=6,802; p<.0005). L&I was listed as an expected payer for 86.9% of Latinos, compared with 72.9% of non-Latinos (p<.0005).

To evaluate the relationships between payer, WC claim linkage, and ethnicity, we constructed a relatively homogenous set of injuries to minimize issues of differential coverage by L&I and differential recording of insurance information (having L&I listed as a payer may displace recording of other insurance), as well as reducing the chance of L&I having been recorded as a payer related to a crime victim rather than work-related claim (more likely for assaults and traffic injuries[82]). Injuries were included if the place of injury was an industrial location and the cause of injury was in the categories of: (1) falls, (2) machinery, (3) struck by/against, or (4) cut/pierce. These categories accounted for 42.3% of the work-related injuries in this sample. L&I was listed as a payer for 81.3% of this group, compared with 66.1% for work-related injuries not in this group. To test whether the odds of having a linked WC claim differed specifically for Latinos among those with L&I listed as a payer (and thus presumably covered by L&I), we used a logistic regression model with robust variance estimates adjusted for multiple injury events for the same worker, restricted as described above, and included the following covariates: a flag for whether insurance other than L&I was listed as a payer, year of injury, sex, age categories (16-24, 25-34, 35-44, 45-54, 55-64, 65 and older), and ISS categories (1-8, 9-15, 16-75).

In the restricted sample described above, 10.4% of Latinos had insurance other than L&I listed as a payer, compared with 20.9% of non-Latinos (N=2,990; p<.0005), and L&I was listed as an expected payer for 89.6% of Latinos, compared with 82.3% of non-Latinos (p<.0005). As shown in **Table 28**, Latinos were more likely to have a linked WC claim, but the differential was restricted primarily to those who did not have L&I listed as a payer, and more particularly to those not having L&I listed as a payer but also having other insurance. Injury severity did not significantly differ across these subgroups. For workers without L&I noted as a payer but who did have a linked WC claim, the delay from injury to WC claim filing was 3 times as long on average as for others in the restricted sample (36 days compared with 12 days, p=.0007).

Among those with L&I listed as a payer (and thus presumably covered by L&I), there was no significant difference in the odds of having a linked WC claim for Latinos compared with non-Latinos after controlling for age, sex, year of injury, ISS, and other insurance (OR: 1.2, 95% CI: 0.9, 1.6). However, the odds of having a linked WC claim were 57% lower for workers with other insurance listed compared with workers with no other insurance listed.

TABLE 28. Expected payer and workers' compensation (WC) claim linkage by ethnicity (restricted sample, N=2,990[a])

L&I as payer	Other insurance	N	% Latino	% linked to WC claim Latino	Non-Latino	Overall	P-value
All	All	2,990	18.4	81.2	71.2	73.0	<0005
Yes	No	2,308	20.2	87.4	84.2	84.8	.09
Yes	Yes	193	13.0	72.0	70.8	71.0	.91
No	No	116	21.6	24.0	14.3	16.4	.25
No	Yes	373	8.6	43.8	16.4	18.8	<.0005

[a] Cases were restricted to those with a place of injury=industrial and a cause of injury=fall, machinery, struck by/against, or cut/pierce. Cases with missing payer or ethnicity information were excluded.

A recurring theme throughout this section is that differential access to health insurance coverage other than WC, as well as adaptation by health care settings to changing economies and financial pressures, may have an important impact on observed trends in both expected payer and linkage to a WC claim. These issues may also impact measurement of trends in occupational injury incidence and reporting, especially when using WC as a proxy for work-relatedness.

We found that work-related injury events reported to the WTR were increasingly likely over time to have L&I as a payer or to be uninsured (**Figure 11**). The percent with other insurance listed as a payer did not measurably change. Given trends in insurance coverage, we would have expected the percentage with other insurance to drop over time. According to the Washington State Population Survey, the percentage of the Washington population lacking any health insurance has increased monotonically from 8.4% in 2000 to 11.0% in 2008, and the percentage of workers with employer/union-paid health insurance has monotonically decreased from 63.4% to 59.9% over the same time period.[83] This pattern in combination with our findings suggests that there may have been increasingly intensive efforts by trauma hospitals to identify potential payers, a documented cost recovery strategy.[84]

Linkage to an accepted compensable WC claim served as a more direct confirmation of payer than whether WC was recorded as an expected payer in the WTR. The overall percentage of WTR injuries linking to a compensable WC claim rose slightly over time. The rise was driven not by those injuries having L&I listed as a payer, but rather by injuries with no insurance coverage, and, to an even greater extent, injuries with other insurance. The differential increase could be related to increasing efforts by insurance companies and/or hospitals to ensure that a WC claim was filed for a work-related injury. These efforts may continue after the expected payer fields are reported to the WTR. Using the restricted sample, we found that Latinos were more likely to have a linked WC claim, but that the differential was restricted primarily to workers who did not have L&I listed as a payer, and even more particularly to workers who did not have L&I listed as a payer but did have other insurance. This may represent workers who were initially reluctant to file a claim or mention L&I as a potential payer but then expensive hospital bills and/or denials by other insurance due to work-relatedness made filing of a WC claim necessary. These issues might have had more effect on Latinos due to differential wealth and resources, or perhaps due to workers becoming aware at a later time that L&I does cover work-related injuries regardless of immigration status. Although we cannot confirm these potential mechanisms, the delay from injury to WC claim filing was 3 times longer on average for workers without L&I noted as a payer but who did have a linked WC claim compared with others in the restricted sample (36 days compared with 12 days, p=.0007), suggesting that identifying the proper payer took some time. This also suggests that the hospital's inability to identify L&I as a payer upfront, for whatever reason, leads to longer delays until claim filing, which has been associated with poorer outcomes for injured workers.[15,85-87]

Compared with non-Latinos, Latinos were more likely to have L&I listed as an expected payer (87% compared with 73%), and much less likely to have other insurance listed (14% compared with 31%). It is possible that Latinos are more likely to be in covered rather than uncovered employment in Washington State, but we were unable to identify relevant estimates. Earlier trauma registry-based studies have also reported that Latinos were more likely to have WC listed as a payer.[7,88] This seems counter-intuitive at first glance, given higher barriers to claim-filing among more vulnerable populations that might be expected to more heavily impact Latino workers.[16,89] Friedman and Forst suggested that this observation could be due to Latinos being less likely to report to the trauma hospital that an injury was work-related, even though WC was eventually identified as a payer (2008). Higher uninsurance rates for Latinos may provide an

additional explanation. According to the 2008 Washington State Population Survey, Hispanic residents were almost twice as likely to be uninsured.[90] In Washington State, the health care provider diagnosing and treating a work-related injury is required to file the initial report of accident that serves to initiate a WC claim and allows for health care cost reimbursement. Hospitals should be highly motivated to recoup the costs of treating severe work-related injuries, and would perhaps be particularly motivated to ensure a WC claim were filed if no other payer were available. It is possible that Latinos more often had WC listed as an expected payer and more often had a WC claim filed simply due to their disproportionate lack of other insurance coverage. For the subset of workers in the restricted sample with L&I listed as a payer (and thus presumably covered by L&I), there was no significant difference in the odds of having a linked WC claim for Latinos compared with non-Latinos after controlling for age, sex, year of injury, ISS, and other insurance.

Among those in the restricted sample with L&I listed as a payer, the odds of having a linked WC claim, after controlling for age, sex, ethnicity, year of injury, and ISS, were 57% lower for workers with other insurance compared with workers with no other insurance. This suggests the possibility of some degree of cost-shifting to other private/government insurance, since these workers were presumably injured in covered employment. However, it is also possible that L&I was erroneously recorded as a payer due to uncertainty about whether the injury or employment was actually covered by L&I.

This was not the ideal data set for evaluating the relationship of severity with expected payer or linkage to a WC claim, since it included only relatively severe injuries. Higher severity is associated with less underreporting, and there are fewer barriers to determining causality for trauma compared with chronic injuries or illnesses.[18,91] In fact, we observed no significant association between injury severity and linkage to a WC claim. However, we did observe a differential with respect to payer. Workers with more severe injuries were significantly more likely to have other insurance listed as a payer, alone or in addition to L&I (**Table 25**). The mechanism is unknown, but could be related to hospitals being more highly motivated to identify all potential payers for more severe (and presumably more costly) injuries. A recent study at a Level I trauma center also found that higher severity patients were more likely to have an identified payer.[92]

In Washington State, the covered population does not include federal employees or exempt/excluded employment.[26] Federal WC coverage would have been captured in the other insurance payer category. There are a number of jobs that are exempt or excluded from mandatory coverage by L&I (e.g., the self-employed, corporate officers, certain domestic/household workers, racing jockeys, etc.), but optional coverage is often available. In this study, we found that 27.4% of work-related injuries did not have L&I listed as a payer, and 36.8% did not link to an accepted compensable WC claim. These percentages are comparable to rough unpublished L&I estimates, based on Washington State Employment Security Department and Bureau of Labor Statistics Current Employment Statistics data, that approximately 25% to 36% of the workforce falls outside L&I coverage. Other studies have found similar percentages of occupational injuries that did not have WC listed as a payer; e.g., 25% in a study based on the Illinois Trauma Registry,[7] and 20% in several studies using hospital discharge or emergency department data.[93,94] Although underreporting is pervasive and may account for some of the injuries in the unlinked column of **Table 27**,[4,18,95] it is likely that non-covered employment accounts for the majority of these relatively severe injuries. Injured workers without a linked WC claim tended to be older and were more likely to have no insurance. They were more likely to have been injured at home or in a motor vehicle traffic incident, and less likely to have been injured at an industrial location or by machinery.

Unfortunately, the WTR does not contain information on occupation and industry, which would be key information for directing policy and prevention activities for workers not covered by WC.

Contrary to expectations, we observed no decrease over time in the percentage of injuries covered by WC, measured either by (1) L&I as an expected payer or (2) linkage to a WC claim. There has been evidence of growth in precarious employment (such as temporary work, contracted employment, telecommuting, and home-based work), which would be less likely to provide WC coverage,[16,96] as well as increasing rates of underreporting and cost-shifting from WC to other public or private health care coverage and/or workers themselves.[16,17,19,97] We think it likely that such trends were overshadowed in our study by the increasingly intensive efforts by hospitals to recoup the costs of care for the particularly expensive and severe set of injuries contained in this data set.

Conclusions

This study involved the first use of the WTR for surveillance of severe occupational traumatic injuries. The WTR has potential to serve as an additional source of surveillance data to more fully capture the burden of severe occupational traumatic injury in Washington State, including improved case ascertainment for severe occupational injuries, the identification of populations at high risk and the identification of new or emerging injury patterns. In addition, it has the potential to contribute valuable information to the planning, implementation and evaluation of programs related to occupational traumatic injury prevention. Although the WTR presents several limitations for surveillance, including incomplete injury coverage and inter-hospital variation in reporting practices, the WTR is well-positioned to capture several types of severe high-priority work-related traumatic injuries, including motor vehicle crashes, falls, and traumatic head and brain injury. In addition, the WTR contains injury information that is not commonly available in other databases, including severity and details of the injury and initial treatment. These statements are likely true of any number of state trauma registries and we are hopeful that the use of state trauma registries for occupational injury research will continue to be explored around the country. This study also provides important exploratory information for occupational health researchers anticipating a fully developed population-based national trauma registry. State trauma registries vary considerably in reporting requirements, inclusion criteria, data elements, and coding conventions.[22,23] The American College of Surgeons has made progress by developing the National Trauma Data Bank (NTDB) and issuing the National Trauma Data Standard, which specifies that participating trauma centers should collect occupation and occupational industry for all injuries flagged as work-related (not currently available in the WTR).[24] However, the NTDB is currently represented as a convenience rather than population-based sample.

We found no evidence of a decreasing trend in work-related traumatic injuries reported to the WTR from 2003 through 2008, using either raw reports or age-adjusted rates based on employed population estimates. In fact, the evidence suggests the opposite is more likely the case. Trauma registry data may avoid some recognized reporting filters,[4] specifically whether a WC claim is filed or accepted for a particular injury or whether an employer recognizes and reports a particular injury as work-related, which may account for the differences between our findings and those based on other data sources. These reporting filters would be less likely to affect the most severe occupational injuries, and we focused on a select subset of severe traumatic injuries for trend analysis. On the other hand, the trends we observed are so strikingly different from those based on most other data sources that they raise a number of questions. It may be that trends in the incidence of the most severe injuries differ from those of less severe

injuries, that there has been an expansion over time in employment falling outside the scope of WC coverage and/or SOII surveys, or that we observed these trends due to limitations inherent in using the WTR for surveillance or due to the particular years involved (there is some evidence that the downward trend in WC claims involving immediate hospitalization was unusually flat during these years). Further research will be required to understand whether rates are differentially increasing for the most severe traumatic occupational injuries, and what this might mean for occupational injury prevention efforts.

Latinos bear an increasingly disproportionate burden of occupational injuries and are less likely to have health insurance coverage aside from workers' compensation. On top of their disproportionate injury burden (which we found also to be disproportionately increasing over time), Latinos are less likely to have health insurance coverage. This reinforces the need to encourage prompt filing of the first report of injury by clinicians in order to avoid the potential for delayed or inadequate treatment of occupational injuries due to lack of a payer.

Many studies have used WC data for occupational injury surveillance and research, but it is difficult to obtain information about injured workers who do not file WC claims, either due to access barriers or to not being covered. The WTR's work-related field was highly sensitive and specific, in contrast to an E code-based indicator previously developed for hospital discharge databases,[3] and provides an unusual opportunity to describe this population. Nearly 37% of the injuries identified by the work-related indicator did not link to a compensable WC claim. If used to supplement WC claims data, the work-related indicator may be useful to identify injuries that occur in the course of exempt/excluded employment, are not reported to WC, and/or are work-related using definitions that go beyond WC coverage. However, despite its other useful features, a recurring theme throughout this set of studies was the lack of adequate work-related information in the WTR. Effective policy and prevention efforts require the isolation of preventable injuries with respect to occupation, industry, and specific populations. Along with other occupational injury researchers before us, we call for the addition of occupation, industry, and other important work-related information such as work status (e.g., full-time or part-time traditional employment, self-employed, family business, temporary agency, contingent employment, casual/day labor, etc.), nativity, language, income, and educational level to trauma registries, electronic medical records, and hospital discharge databases.[5,98,99]

We found that linkage between trauma registry and WC databases is feasible and shows promise for enhancing occupational health services research. Although minimally defined, the work-related indicator is highly sensitive and specific and may be useful as an independent identifier of work-related traumatic injuries. The race/ethnicity information found in the WTR can be linked to WC claims data to enable disparities research. Linking WTR and WC records allowed for combining the rich injury detail from the WTR with long-term outcome and cost information, enabling more comprehensive occupational injury research.

In just one example of a useful application, we used WTR data as a gold standard to evaluate OIICS-based case definitions for TBI. OIICS-based case definitions were highly specific but had low sensitivity, capturing less than a third of fatal and nonfatal TBI. Much TBI was obscured within multiple traumatic injury and/or multiple body part OIICS categories. Systematic underestimation of the prevalence of work-related TBI directly hinders surveillance efforts. The use of OIICS versus ICD-9-CM codes changed the observed attributable cause distribution, with important implications for prevention efforts. Further research to develop an OIICS-based TBI case definition is indicated. As efforts develop to document the incidence and importance of work-related TBI across the U.S., attention must be paid to developing surveillance methods that can more fully and accurately capture its impact.

We conducted this study in part as an effort toward addressing the clear need for better severity measures for occupational health services research.[81] This study demonstrated that AIS-based injury severity measures were significantly associated with work disability and medical cost outcomes for work-related injuries. Injury severity can be estimated using either ICDMAP-90 or -icdpic- when ICD-9-CM codes are available. We observed little practical difference between severity measures or scoring methods. Although commonly used in trauma research, AIS-based injury severity measures have rarely been used in occupational injury research. However, there are potentially a variety of novel and important applications for occupational injury research and surveillance, including risk adjustment for program evaluation, intervention, or outcome studies, or severity restriction when constructing comparison groups or case definitions for surveillance.

Trauma registries have limitations for surveillance of occupational traumatic injuries due to cross-state and secular variation in inclusion criteria and the completeness of trauma coverage.[22,23,100] The WTR does not capture data for the many occupational injuries that do not meet inclusion criteria, particularly minor injuries that do not require hospital-based care. In addition, occupational fatalities can occur in any setting and only those occurring after contact with the EMS and trauma system are reported to the WTR. However, although hospital discharge data are more broadly population-based, their use requires reliance on payer to identify work-related injuries, effectively excluding work injuries either not covered by or not reported to workers' compensation. Payer information is particularly problematic in Washington State, as the same expected payer code (L&I) is used to indicate both WC (either State Fund or self-insured) and crime victim compensation claims, and it is not possible to distinguish between the two (this applies both to hospital discharge data/CHARS and to WTR data). The use of trauma registry data offers an alternate method of identifying work-related injuries, whether or not they are reported to, billed to, or covered by L&I.

This study demonstrated the importance of considering differential access to other insurance coverage and adaptation by health care settings to changing economies and financial pressures when assessing trends in occupational injury incidence and reporting, especially when using WC as a proxy for work-relatedness. Our study confirms that WC being identified as an expected payer did not mean a WC claim would be filed and accepted, and many work-related injuries (identified via linkage to an accepted WC claim) could not be identified using the payer fields alone. There is a need for further research into the impact of health insurance coverage on the likelihood of a WC claim being filed and the magnitude and importance of potential cost-shifting from WC to other insurance and to workers themselves. There is also a need to consider whether employment/work relationships have changed to the extent that the scope of mandatory WC coverage should be expanded as a matter of policy.

Inclusion Enrollment Report

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

Study Title: Use of the Washington State Trauma Registry for Occupational Injury Surveillance

Total Enrollment: 614,133 **Protocol Number:** N/A

Grant Number: 5 R03 OH009883

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	1,406	5,316	0	6,722 **
Not Hispanic or Latino	28,460	47,225	2	75,687
Unknown (individuals not reporting ethnicity)	197,780	333,922	22	531,724
Ethnic Category: Total of All Subjects*	227,646	386,463	24	614,133 *
Racial Categories				
American Indian/Alaska Native	587	1,147	0	1,734
Asian	1,194	1,690	0	2,884
Native Hawaiian or Other Pacific Islander	***	***	***	***
Black or African American	1,042	3,074	0	4,116
White	34,501	51,556	6	86,063
More Than One Race	371	1,208	0	1,579
Unknown or Not Reported	189,951	327,788	18	517,757
Racial Categories: Total of All Subjects*	227,646	386,463	24	614,133 *

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	10	14	0	24
Asian	9	30	0	39
Native Hawaiian or Other Pacific Islander	***	***	***	***
Black or African American	31	65	0	96
White	674	2,352	0	3,026
More Than One Race	143	645	0	788
Unknown or Not Reported	539	2,210	0	2,749
Racial Categories: Total of Hispanics or Latinos**	1,406	5,316	0	6,722 **

* 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, Adams D, Silverstein BA: [2011] Occupational injury surveillance using the Washington State Trauma Registry. Journal of Occupational and Environmental Medicine 53(11):1243-1250.

This manuscript addresses Specific Aim 1. In it, we describe and document the WTR as a resource for occupational injury surveillance and research. It summarizes descriptive statistics related to work-related traumatic injuries captured by the WTR, including demographics, payer, injury descriptors, severity, and pre-existing conditions. It also describes trends in work-related occupational injuries captured by the WTR.

2. Sears JM, Bowman SM, Silverstein BA, Adams D: [2012] Identification of work-related injuries in a state trauma registry. Journal of Occupational and Environmental Medicine 54(3):356-362.

This manuscript addresses Specific Aim 2. We assessed three methods of identifying work-related injuries in the WTR (the WTR work-related field, payer, and an indicator based on E-codes), using linkage to accepted compensable WC claims as a partial gold standard.

3. Sears JM, Blanar L, Bowman SM, Adams D, Silverstein BA: [2012] Predicting work-related disability and medical cost outcomes: Estimating injury severity scores from workers' compensation data. Journal of Occupational Rehabilitation. Published Online First: June 26, 2012. doi:10.1007/s10926-012-9377-x.

This manuscript addresses Specific Aim 2. We assessed: (1) the feasibility of estimating Abbreviated Injury Scale-based injury severity scores (ISS) from ICD-9-CM codes available in workers' compensation (WC) medical billing data, (2) whether ISS predicts work-related disability and medical cost outcomes, (3) whether ISS adds value over other injury severity proxies, and (4) whether the utility of ISS differs for an all-injury sample compared with three specific injury samples (amputations, extremity fractures, traumatic brain injury). It also presents information about which WC claims are most completely represented in the WTR.

4. Sears JM, Bowman SM, Silverstein BA: [2012] Trends in the disproportionate burden of work-related traumatic injuries sustained by Latinos. Journal of Occupational and Environmental Medicine 54(10):1239-1245.

This manuscript addresses Specific Aim 1. WTR data were used to describe trends in the burden of work-related traumatic injuries sustained by Latinos in Washington State.

5. Sears JM, Graves JM, Blanar L, Bowman SM: [In press] Case identification of work-related traumatic brain injury using the Occupational Injury and Illness Classification System (OIICS). Journal of Occupational and Environmental Medicine.

This manuscript addresses Specific Aims 2 and 3. We described the accuracy and completeness of case classification and case-finding for various OIICS-based case definitions for traumatic brain injury (TBI), using clinically-identified TBI in WTR data as the gold standard.

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. Workers' compensation claims data do not include any information on race or ethnicity, and comprised the vast majority of data used for this study. All study procedures relied on secondary analyses of existing data and subjects were not contacted (a waiver of consent/authorization was obtained).

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 who file workers' compensation claims 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. One product of this study was an analysis of work-related traumatic brain injury among young workers (16-24). (The manuscript is currently under review, so is not listed in the publications section.)

Materials Available for Other Investigators

N/A

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