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Predicting work-related disability and medical cost outcomes: A comparison of injury severity scoring methods

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ABSTRACT

Introduction: Acute work-related trauma is a leading cause of death and disability among U.S. workers. Occupational health services researchers have described the pressing need to identify valid injury severity measures for purposes such as case-mix adjustment and the construction of appropriate comparison groups in programme evaluation, intervention, quality improvement, and outcome studies. The objective of this study was to compare the performance of several injury severity scores and scoring methods in the context of predicting work-related disability and medical cost outcomes.

Methods: Washington State Trauma Registry (WTR) records for injuries treated from 1998 to 2008 were linked with workers' compensation claims. Several Abbreviated Injury Scale (AIS)-based injury severity measures (ISS, New ISS, maximum AIS) were estimated directly from ICD-9-CM codes using two software packages: (1) ICDMAP-90, and (2) Stata's user-written ICDPIC programme (ICDPIC). ICDMAP-90 and ICDPIC scores were compared with existing WTR scores using the Akaike Information Criterion, amount of variance explained, and estimated effects on outcomes. Competing risks survival analysis was used to evaluate work disability outcomes. Adjusted total medical costs were modelled using linear regression.

Results: The linked sample contained 6052 work-related injury events. There was substantial agreement between WTR scores and those estimated by ICDMAP-90 (kappa = 0.73), and between WTR scores and those estimated by ICDPIC (kappa = 0.68). Work disability and medical costs increased monotonically with injury severity, and injury severity was a significant predictor of work disability and medical cost outcomes in all models. WTR and ICDMAP-90 scores performed better with regard to predicting outcomes than did ICDPIC scores, but effect estimates were similar. Of the three severity measures, maxAIS was usually weakest, except when predicting total permanent disability.

Conclusions: Injury severity was 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. This study demonstrated that using existing software to estimate injury severity may be useful to enhance occupational injury surveillance and research.

Introduction

Acute work-related trauma is a leading cause of death and disability among U.S. workers. Every day, approximately 9000 workers are treated in emergency departments (EDs), 200 are hospitalized, and 15 die due to traumatic injuries.[1] Severe traumatic injury can lead to long-term pain and disability and is very costly for workers' compensation (WC) systems and society as a whole. The total cost of occupational injuries was recently estimated at $192 billion annually.[2]

Occupational health services researchers have described the pressing need to identify valid injury severity measures for purposes such as case-mix adjustment and the construction of appropriate comparison groups in programme evaluation, intervention, quality improvement, and outcome studies.[3] Trauma registries typically contain injury severity measures based on the Abbreviated Injury Scale (AIS),[4,5] and occupational injury researchers have begun to explore state trauma registries as a resource.[6–8] In contrast, administrative databases often used for occupational

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health services research, such as workers' compensation claims databases and hospital discharge datasets, do not contain injury severity measures but often do contain ICD-9-CM diagnosis codes. Our primary motivation was to compare various methods of estimating AIS-based injury severity from ICD-9-CM codes for potential use in studies involving common occupational health services outcomes such as the amount of compensated time lost from work, the total medical cost of a work-related injury, and permanent work disability.Two software packages that estimate injury severity directly from ICD-9-CM codes have been used for injury research: (1) ICDMAP-90 software (ICDMAP) developed by and available from the Johns Hopkins Bloomberg School of Public Health,[9] and (2) Stata's user-written ICDPIC suite of programmes (ICDPIC), developed using National Trauma Data Bank (NTDB) data to assign approximate injury severity scores by classifying injuries into general severity and body region categories.[10] ICDMAP 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 scores are now included in some ED discharge files released by the Healthcare Cost and Utilization Project (HCUP). However, validation studies of ICD-9-CM-based scores have not produced uniformly reassuring results.[9,11–14]

AIS-based injury severity scores have been validated for prediction of mortality,[15–19] but there have been mixed findings regarding prediction of work-related outcomes. Many studies have found no association, but most such studies have been small-scale and focused on functional capacity or short-term work status rather than longer-term outcomes such as total lost work time, total costs, or total permanent disability. The few studies that have used a continuous measure of work disability along with survival analysis or regression methods have found a significant association between injury severity and work disability.[20–23] In a recent related study, we used ICDPIC-based injury severity scores (ISS) estimated from WC billing data to demonstrate that ISS was significantly associated with work disability and medical cost outcomes for work-related injuries.[23] However, we did not compare ICDPIC head-to-head with ICDMAP, nor have we been able to identify any such comparison in the literature. The current study expands on our previous work, comparing ICDPIC with ICDMAP and with trauma registry-based scores, as well as comparing other types of AIS-based injury severity measures with ISS.

Objective

The objective of this study was to compare the performance of several injury severity scores and scoring methods in the context of predicting work-related disability and medical cost outcomes. To accomplish this objective, we linked injury data from a state trauma registry with outcomes data from WC claims for a large sample of work-related injuries.

Methods

Study population and data sources

This retrospective cohort study linked data from: (1) the Washington State Trauma Registry (WTR), maintained by the Washington State Department of Health, and (2) WC claims data, maintained by the Washington State Department of Labor and Industries. The WTR contains traumatic injuries meeting specific inclusion criteria from all state-designated acute trauma care facilities, including at least one of the following: trauma resuscitation team activation, dead on arrival or death during hospital stay, interfacility transfer by Emergency Medical Services or ambulance, or inpatient admission of at least 48 hours. Washington State has a single payer WC system (State Fund) that covers approximately 70% of those workers covered by the Industrial Insurance Act.[24] Self-insured employers account for the remainder. All WTR cases and all compensable WC claims were requested for workers injured from 1998 to 2008, excluding those younger than 16 and injuries occurring outside Washington State. Records were linked and deduplicated using The Link King, a public domain software program developed in Washington State for deterministic and probabilistic linkage of administrative records.[25] Further details about the data sources and linkage procedures are described in previous related publications.[8,26] This study was approved by the Washington State Institutional Review Board.

Our sample included injuries that involved at least one ICD-9-CM diagnostic code for a traumatic injury as specified by the National Trauma Data Bank (800–904.9, 910–929.9, 950–957.9, 959–959.9).[27] Isolated burns were excluded because ICDPIC does not score burns. In addition, AIS-based injury severity scores do not reliably classify burns due to the importance of inhalation injuries (inhalation injuries are not scored by AIS). Proximate fatalities (e.g., before or during the initial hospitalization, or accepted fatal WC claims filed by survivors) 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 scoring concordance assessments, due to unavailable outcomes data.

Samples and outcomes

We assessed the association of injury severity scores with outcome measures using two samples: (1) all injured workers, and (2) a subset of workers with traumatic brain injuries (TBI). We followed the CDC case definition for TBI: 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.[28] Outcomes data were extracted from WC claims data in December 2010, providing 2–13 years of follow-up.

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 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.[29] TPD is determined when medical and vocational evaluations indicate that the injury prevents the worker from ever becoming gainfully employed.

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

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[15] 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,[16,17] and (3) the overall maximum AIS (maxAIS), which performs as well as the ISS in at least some circumstances.[18,19] AIS ranges from 1 (minor) to 6 (non survivable). 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 1–75, with 75 assigned whenever maxAIS is 6. For simplicity of

Table 1
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	4700	3593 (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	4410	3997 (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; TPD, total permanent disability; TBI, traumatic brain injury.

presentation and comparison, we entered each score as the sole continuous variable in each regression model (alternate parameterizations are described in the Discussion section).

Each of these scores was contained in the WTR or calculated directly from the WTR's AIS 90 fields. Where scores varied, we used the scores from the definitive care hospital, per the advice of WTR staff. Each score was also estimated from the ICD-9-CM diagnosis codes available in the WTR using both ICDMAP and ICDPIC. We compared these two scoring methods head-to-head with existing WTR scores, as possible alternative methods of deriving injury severity scores from medical billing/discharge records outside the trauma registry system.

Data analysis

Analyses were performed using Stata/SE 11.2 for Windows (StataCorp LP, College Station, TX). All figures were based on the WTR ISS. Concordance between the three scoring methods for a 6-category version of ISS (1–8, 9–15, 16–24, 25–40, 41–49, and 50–75) was assessed with Cohen's kappa[30] using the 6052 linked cases. Landis and Koch's guidelines were used to assess the results.[30]

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 as the time scale.[31] 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-[32] (based on the Fine and Gray semiparametric method[33]) was used to produce subhazard ratios (SHR) for each outcome event of interest. Adjusted total medical costs were modelled using ordinary least squares regression (OLS) with robust variance estimates.[34]

The Akaike Information Criterion (AIC)[35] allows for direct comparison of non-nested models with the same outcome variable and sample size. A lower relative AIC indicates more information content. AIC rewards goodness of fit and penalizes increasing degrees of freedom. For each set of models (based on the same sample and outcome), we calculated delta AIC (ΔAIC) by subtracting the lowest AIC from the AIC for each of the other models in that set. The larger the ΔAIC, the more information was lost from that model relative to the best model (for which ΔAIC = 0). Differences in amount of variance explained (R^2) and estimated effects (SHR and OLS coefficients) were also compared (however, R^2 cannot be calculated for competing risk models).

Results

Our linked sample contained 6052 work-related injury events. Self-insured claims that met the inclusion criteria (N = 927) were included only for scoring concordance assessments, due to unavailable outcomes data. The sample used for work disability analyses consisted of 4700 injured workers (932 for the TBI subset). The sample used for medical cost analyses consisted of 4410 injuries (802 for the TBI subset).

There was substantial agreement between WTR and ICDMAP classification of injuries into the six ISS categories (kappa = 0.73), as well as between WTR and ICDPIC classification (kappa = 0.68). There was almost perfect agreement between ICDMAP and ICDPIC classification (kappa = 0.89).

Table 1 presents the observed outcome distribution for each of the four samples. As shown in Fig. 1, 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.

Fig. 2 presents a series of stacked cumulative incidence plots that display the estimated relative probability of each outcome over time by injury severity and sample.[32] 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 and somewhat larger for TBI than for all injuries. Minor injuries had a more convex curve for time loss ending without TPD, indicating more rapid resolution of the claim.

Table 2 presents the results of the competing risk models used to assess the effect of injury severity on work disability. All models were highly significant ($p \leq 0.00005$ for all-injury models, $p \leq 0.0002$ for TBI-only models). Within score type, models using the WTR and ICDMAP 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).

As shown in Fig. 3, there was a large monotonic increase in both median and mean adjusted total medical costs as injury severity increased. Table 3 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 ($p \leq 0.00005$).

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 $4300–5100 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.

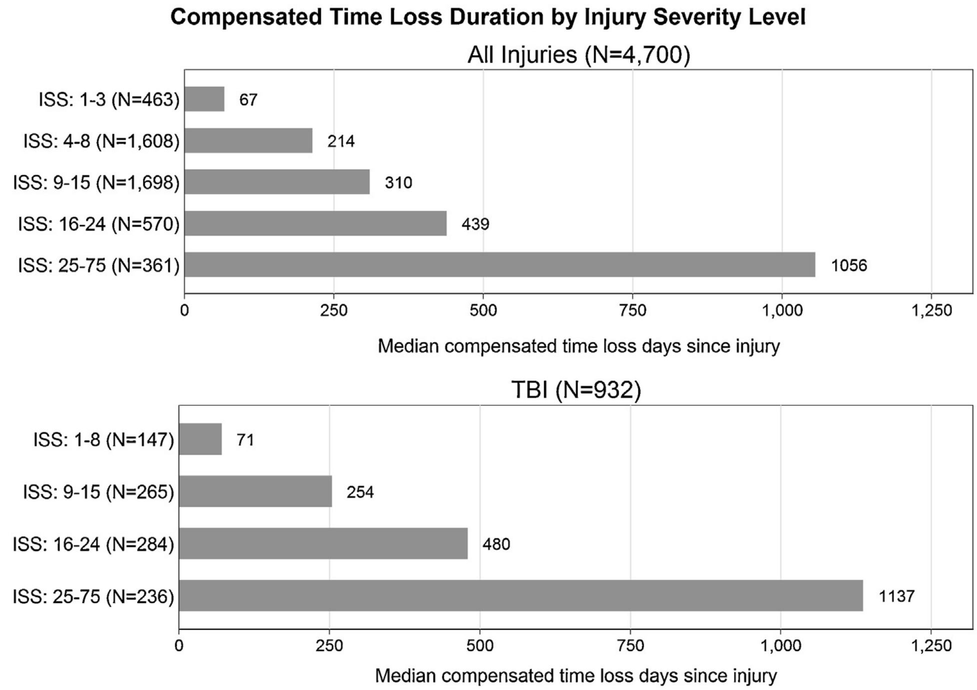

Fig. 1. This figure shows the large monotonic increase in median days to the end of time loss compensation as injury severity increased. An extra category (ISS: 1–3) was broken out to show the consistent trend (there were too few cases to do the same for TBI).

Discussion

This study demonstrated that AIS-based injury severity measures were significantly associated with work disability and medical cost outcomes. Work disability and costs increased monotonically with injury severity. These conclusions held up for all three scoring methods, although ICDPIC generally did not perform quite as well as the WTR scores or ICDMAP. Although there

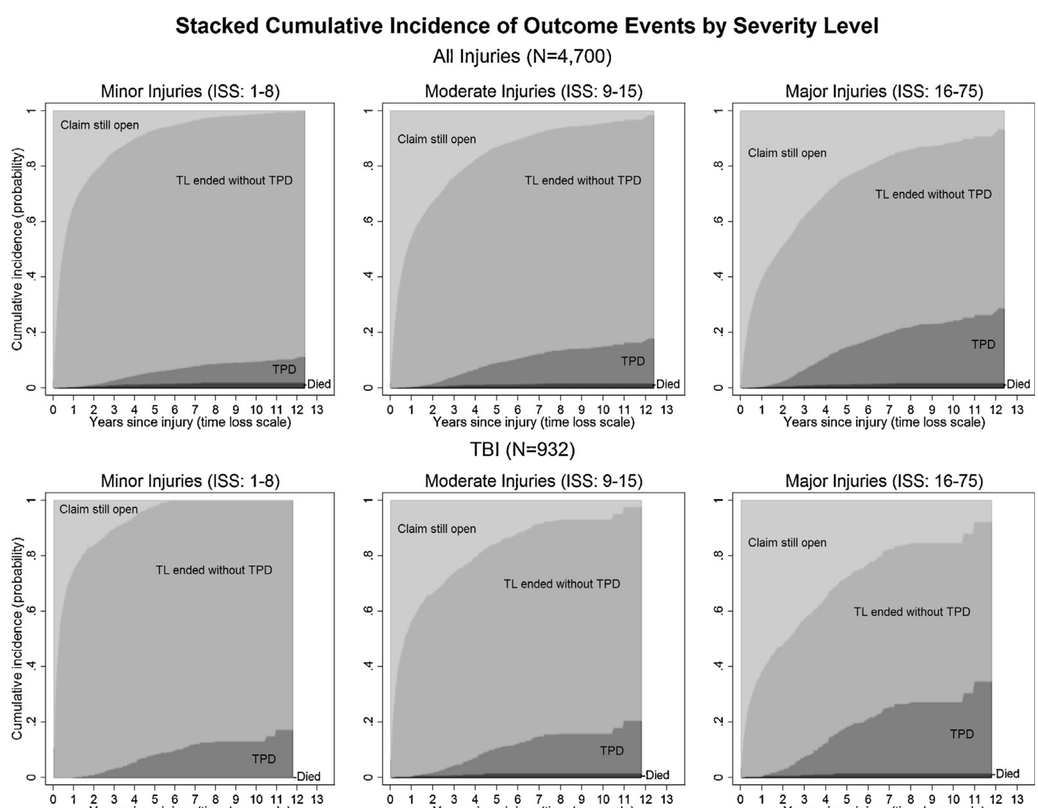

Fig. 2. These two series of stacked cumulative incidence plots show the estimated relative probability of each competing outcome over time, by injury severity. The cumulative incidence of each of the competing outcomes (including censored status) sums to 1 at every point in time.

Table 2
Work disability outcomes, competing risks survival analysis.

Sample/Outcome	Score type	Scoring method					
		WTR		ICDMAP		ICDPIC	
		SHR	ΔAIC	SHR	ΔAIC	SHR	ΔAIC
All injuries (*N* = 4700)							
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 ΔAIC = 0 (bold). 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).
WTR, Washington State Trauma Registry; SHR, subhazard ratio; AIC, Akaike Information Criterion; TL, time loss; TPD, total permanent disability; 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.

were clear differences in model fit and information content, there was little practical difference between the three scoring methods in terms of the resulting effect estimates. Of the three measures we evaluated, maxAIS usually performed the weakest; however maxAIS performed better for the TPD outcome. The worst injury may be more important in predicting total permanent disability, while a summary of the severity of all injuries may be more important in predicting duration of work disability assuming eventual recovery.

We limited our presentation of results to continuous versions of each injury severity score, despite existing evidence of non-continuity in these scores.[36–38] We also tested a number of alternate parameterizations, which we have not presented here (e.g., a dummy for each of the 6 levels of maxAIS, dummies for ISS/NISS categories based on guidance by Copes et al.,[36] squaring maxAIS, etc.). In general, these alternatives improved model fit and the amount of information provided. There appeared to be some benefit in allowing for flexibility with regards to the independent effects of injury severity by body region (via adding separate AIS variables for each body region), which comports with previous research suggesting that severity for each distinct body region may make a differential and independent contribution to functional outcomes and medical costs.[36,39,40] However, even with a relatively large sample, the additional precision obtained may not warrant the number of additional parameters required. The best choice will vary based on sample size and the number of other variables of interest, as well as the specific outcome variable. We encourage readers to choose the best fitting parameterization based on their own research goals and the characteristics of the sample available.

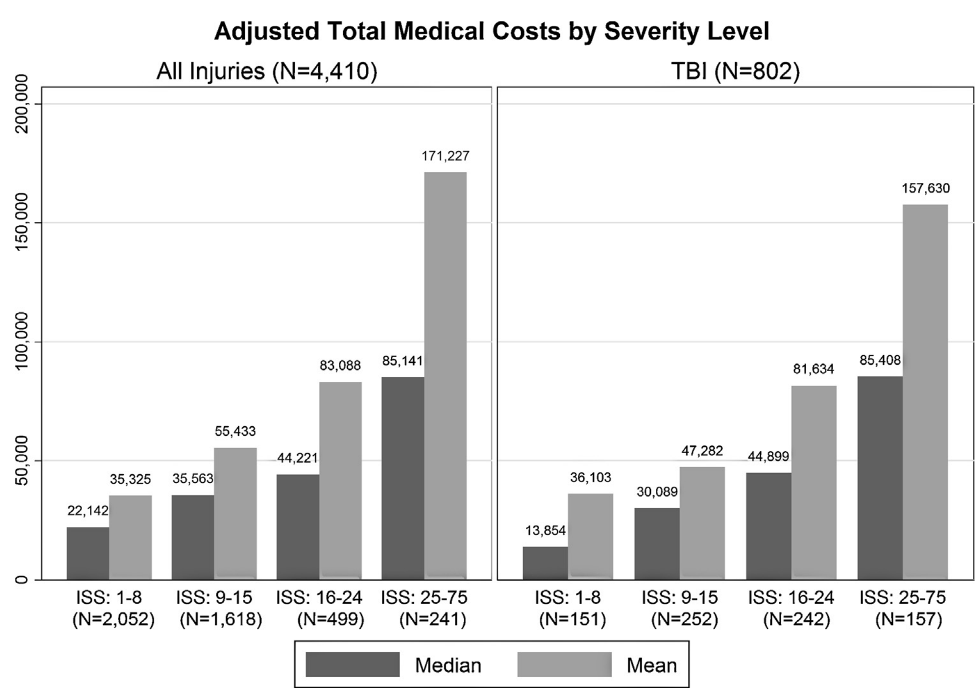

Fig. 3. This graph shows that both median and mean adjusted total medical costs increased monotonically as injury severity increased.

Table 3
Adjusted total medical costs in dollars.

Sample	Score type	Scoring method								
		WTR			ICDMAP			ICDPIC		
		β	R^2	ΔAIC	β	R^2	ΔAIC	β	R^2	ΔAIC
1. All injuries (*N* = 4410)										
	ISS	4304	.061	29	5098	.067	**0**	4490	.052	68
	NISS	3304	.061	30	3793	.064	15	3320	.050	79
	maxAIS	31,367	.044	106	34,380	.047	91	32,253	.040	127
2. TBI (*N* = 802)										
	ISS	4675	.080	8	5850	.089	**0**	5071	.058	27
	NISS	3621	.083	6	4478	.090	**0**	3632	.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 ΔAIC = 0 (bold). 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).
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.

Many factors other than injury severity affect work-related disability and total medical costs. Injury severity predicted a relatively small portion of the variance in costs, but a low R^2 is not unusual for cost models. All disability and cost models were highly significant, despite containing only injury severity information. Results using ICDPIC were reasonably similar to those using WTR scores and ICDMAP, making it feasible for any Stata user to adjust for injury severity when ICD-9-CM codes are available. In the only previous evaluation of ICDPIC that we were able to identify, Di Bartolomeo et al.[11] concluded that ICDPIC agreed poorly with scores estimated by expert trauma registrars. 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.

Strengths and limitations

Our study brought a number of unique strengths to bear on our aims. In contrast to many previous studies that reported no association between injury severity and work disability, we had a large sample available that included a variety of injury types and an unrestricted injury severity range.

ICD-9-CM codes are still in use in some countries, including the U.S. where this study was based. Jurisdictions that have transitioned to ICD-10 will not be able to use ICDMAP or ICDPIC in their present forms to estimate AIS-based injury severity. ICDPIC's underlying tables that crosswalk from ICD-9-CM codes to AIS severity and body region are modifiable by the user, and could be adapted to ICD-10 using a crosswalk. The comparison of ISS, NISS, and maxAIS in this context should be broadly useful.

WTR scores may be based on informed and careful decisions made by trauma surgeons and trauma registrars; however, trauma registrars have quite variable levels of training and experience. These comparisons provide us with a measure of concordance with existing accepted WTR-based measures, rather than with a gold standard.

Finally, the effect estimates presented here are not meant for any purpose other than model comparison within the context of this study. We did not include in our models any of a number of other important factors that are known to affect work disability and medical cost outcomes (e.g., age, gender, health status, availability of job modifications, etc.). In addition, more flexible parameterizations would improve model fit and change effect estimates. Due to censoring, we excluded open claims from the cost models and this differentially excluded more severe injuries, so our findings are conservative estimates of association. Our findings do not directly bear on the performance of these scoring methods with respect to mortality prediction.

Conclusions

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 or ICDPIC when ICD-9-CM codes are available. Even when ICD-9-CM codes are unavailable in WC data, injury severity could be estimated from diagnosis codes obtained by linking with other sources such as hospital discharge records, medical billing data from providers, insurance records, or trauma registry records. Although there were clear differences in model fit and information content, there was little practical difference between WTR scores and ICDMAP or ICDPIC estimates of the effect of injury severity on these outcomes. Our findings provide some reassurance regarding the use of either ICDMAP or ICDPIC software to derive scores directly from ICD-9-CM codes in non-trauma registry data sets.

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 programme evaluation, intervention, or outcome studies, or severity restriction when constructing comparison groups or case definitions for surveillance.

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Conflict of interest statement

The authors declare no conflicts of interest.

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