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The burden of traumatic brain injury among adolescent and young adult workers in Washington State

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Abstract

Objective—This study describes injury characteristics and costs of work-related traumatic brain injury (WRTBI) among 16–24 year olds in Washington State between 1998 and 2008.

Methods—WRTBIs were identified in the Washington Trauma Registry (WTR) and linked to workers' compensation (WC) claims data. Medical and time-loss compensation costs were compared between workers with isolated TBI and TBI with other trauma.

Results—Of 273 WRTBI cases identified, most (61.5%) were TBI with other trauma. One-third of WRTBI did not link to a WC claim. Medical costs averaged $88,307 (median $16,426) for isolated TBI cases, compared to $73,669 (median $41,167) for TBI with other trauma.

Conclusions—Results highlight the financial impact of WRTBI among young workers. Multiple data sources provided a more comprehensive picture than a single data source alone. This linked-data approach holds great potential for future traumatic occupational injury research.

Keywords

Occupational health; Head injuries; Youth; Work-related injuries; Costs of work-related TBI; Workers' compensation data

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INTRODUCTION

Each year in the United States, approximately 1.7 million people sustain traumatic brain injuries (TBI) from falls, motor vehicle crashes, sports, work, and other circumstances (Faul, Xu, Wald, & Coronado, 2010). These injuries result in sizable direct (e.g., medical) and indirect (e.g., lost productivity) costs; recent estimates suggest that the cost burden of TBI in the United States in 2000 was over $110 billion (Corrigan, Selassie, & Orman, 2010). Beyond the financial ramifications of TBI, injured persons may experience long-term cognitive, physical, psychosocial, and emotional health consequences (Langlois, Rutland-Brown, & Wald, 2006). The impacts of TBI on the U.S. population are profound: 43.3% of hospitalized TBI cases experience residual disability 1 year after hospitalization (Selassie et al., 2008), and over 3 million civilian residents in the U.S. are estimated to experience disability associated with previous TBI (Zaloshnja et al., 2008).

Many of these injuries are sustained at the workplace or during work-related activities, and the National Institute for Occupational Safety and Health (NIOSH) has identified work-related traumatic injury research as one of their key priorities (Stout et al., 1998). A recent analysis of work-related TBI (WRTBI) fatalities in the United States found that TBI accounted for 22% of all work-related injury fatalities between 2003 and 2008, and as much as 46% of work-related fall deaths (Tiesman, Konda, & Bell, 2011). The authors suggest that the magnitude of both fatal and nonfatal TBI in the workplace is substantial enough to warrant future research on the topic (Tiesman et al., 2011). Few U.S.-based studies have focused on WRTBI and we were unable to identify any national estimates of the incidence of nonfatal WRTBI. However, a study of occupational injuries using the Washington State Trauma Registry (WTR) found that more than 20% of fatal or nonfatal work-related trauma reported to the registry involved TBI (Sears, Bowman, Adams, & Silverstein, 2011). Related healthcare and workers' compensation costs are substantial and may be underestimated, given the long-term physical and psychological consequences of TBI (Langlois et al., 2006). For example, researchers using Washington State workers' compensation data estimated the median medical, compensation, and pension costs of WRTBI as $61,000 per injured worker (all ages, median; Wrona, 2006).

The long-term repercussions of TBI are substantial among adolescents and young adults, whose brains continue to mature and develop well into their mid-twenties (Pujol, Vendrell, Junque, Marti-Vilalta, & Capdevila, 1993). In 2010, approximately 293,000 adolescents and young adults (ages 15–24) sought emergency department treatment for TBI in the United States (Faul et al., 2010). In this age group, an estimated 3.5% of TBIs were sustained while working (Kim, Colantonio, & Chipman, 2006). Compared to other age groups, young workers have the highest rate of work-related injuries (Jackson, 2001). Several studies that reported WRTBI by age found that 13–23% of all WRTBI occur among young workers (24 years and younger) (Colantonio, et al., 2010; Kim et al., 2006; Wei, Roesler, & Kinde, 2012). For those who sustain TBI before or during adolescence, the economic and physical hardships of treatment and rehabilitation may be compounded by limited return to work or school and diminished attainment of education and vocational milestones (Anderson, Brown, Newitt, & Hoile, 2011; Doctor et al., 2005; Todis, Glang, Bullis, Ettel, & Hood, 2011).

Researchers often rely on workers' compensation (WC) administrative claims data to study occupational injuries and illnesses. While WC sources often provide extensive data on direct and indirect costs associated with occupational injuries, information on the nature and circumstances around injuries tend to be limited (Reville, Bhattacharya, & Sager Weinstein, 2001). Combining WC data with other data sources thus may provide a more accurate and comprehensive picture of the burden and scope of injuries (Reville et al., 2001). Young workers in particular may be less likely to be included in WC data, because they may be often engaged in informal and unpaid work arrangements, for which injuries are not covered by WC programs or systematically reported to surveillance surveys (Runyan & Zakocs, 2000). For these reasons, exploring data sources beyond WC claims may provide valuable information regarding work-related injuries sustained by adolescents and young adults.

Hospital-based injury surveillance systems, such as trauma registries, provide an alternative source of data to examine occupational traumatic injuries including TBI. Many state trauma registries include an indicator of work-relatedness for injuries (Guice, Cassidy, & Mann, 2007), allowing researchers to identify severe, traumatic occupational injuries that may or may not be associated with a compensable WC claim. Trauma registries contain rich clinical data, including detailed information about the injury type and severity that are not typically available in WC claims data. Because of these advantages, researchers have used trauma registry data from several states for occupational injury surveillance (Friedman & Forst, 2007; Husberg, Conway, Moore, & Johnson, 1998; Sears et al., 2011). Linking trauma registry data with WC records allows researchers to leverage data from both sources and generate a richer, more comprehensive dataset that combines detailed injury information with WC outcomes (e.g. total medical and time-loss compensation costs; Sears, Bowman, Silverstein, & Adams, 2012). The combined data may also provide insight into the characteristics of injuries identified as work-related in the trauma registry but not linked to a WC claim.

The purpose of the research is to obtain a broader understanding of the scope and costs of WRTBI among adolescent and young adult workers in Washington State from 1998 through 2008 by examining traumatic occupational injuries reported to the Washington State Trauma Registry (WTR) and subsequently linked to Washington State WC claims. Specifically, this study focuses on WRTBI among adolescent and young adult workers (age 16–24 years) and aims to: (a) compare patient demographics and injury characteristics for injuries that linked to a WC claim with those that did not; and (b) describe the total amount paid for medical costs and time-loss compensation among WRTBI cases that linked to WC claims, specifically comparing isolated TBI to TBI with other trauma.

MATERIALS AND METHODS

Data Sources and Study Population

This study utilized linked data from two separate databases: (a) the Washington State Trauma Registry (WTR), and (b) Washington State WC claims. The WTR, maintained by the Washington State Department of Health, provides detailed information for eligible traumatic injuries that were treated at state-designated acute trauma hospitals. In addition to clinical and procedure information, a field within the WTR database identifies whether an injury was work-related. For most of the years of this study, trauma registry reports were mandatory for patients 16 years and older 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 or ambulance, or inpatient admission of at least 48 hours. Further background on the WTR and its inclusion criteria can be found in a previous related publication (Sears et al., 2011).

The Washington State Department of Labor and Industries (L&I) maintains a single-payer WC system (the State Fund) that covers approximately 70% of those workers as per the Industrial Insurance Act (State of Washington). Self-insured employers account for the remaining 30%. L&I performs the functions of an insurer for State Fund claims, and

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administers the WC system for both State Fund and self-insured employers. L&I maintains a comprehensive administrative claims database for the approximately 200,000 WC claims that are filed each year, allowing for population-based research. However, the covered population does not include federal employees or exempt/excluded employment (e.g., sole proprietors, domestic workers, etc.) (State of Washington Department of Labor and Industries). All compensable WC claims (fatal claims or those involving compensated time loss after the initial three-day post-injury waiting period) were obtained from L&I for eligible injuries. Although self-insured claims were included in this study, they were excluded from analyses of cost outcomes due to inadequate cost data.

Data from the WTR and WC claims were obtained for injuries occurring during the calendar years 1998 through 2008. This study excluded data for injuries among individuals younger than 16 or older than 24 years, those that occurred outside of Washington State, WC claims for L&I employees, and WC claims that did not involve any missed work days after the initial three-day post-injury waiting period (i.e. medical aid-only claims). In a preliminary assessment, we found that very few medical aid-only claims linked to the relatively severe traumatic injuries reported to the WTR.

Records were linked and de-duplicated 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 (Campbell, Deck, & Krupski, 2008). The WTR and WC records were linked by identifying unique individuals within each database and across the two databases, consolidating WTR injury reports for the same injury event for each individual (a single injury event may generate multiple WTR injury reports), and linking specific injury events with associated WC claims within each unique individual (Sears et al., 2012). Detailed database linkage methods are described in detail elsewhere (Sears et al., 2012). This study was approved by the Washington State Department of Social and Health Services Institutional Review Board.

Measures

We defined work-related injuries as those either indicated as being work-related by the WTR (regardless of whether a WC claim existed for the injury) or those WTR injuries that linked to a compensable WC claim (regardless of work-related status in the WTR). The work-related field in the WTR has been shown to be highly sensitive and specific in identifying work-related injuries (Sears et al., 2012).

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 (Marr AL & Coronado VG, 2004). We categorized TBI into two groups, *isolated TBI* and *TBI with other trauma*, based on ICD-9-CM diagnosis codes and maximum Abbreviated Injury Scale (AIS) scores from WTR records. *Isolated TBI* was defined as TBI without indication of additional moderate extracranial injury in the head/neck region based on ICD-9-CM codes (e.g., facial fractures, cervical spine injuries) and maximum AIS score ≤ 1 in body regions other than head/neck (indicating minor injury). *TBI with other trauma* was defined as TBI with an ICD-9-CM code in the head/neck body region indicating at least moderate extracranial injury or maximum AIS score > 1 in at least one body region other than head/neck.

Medical costs and time-loss compensation costs were obtained from WC data. Self-insured claims were excluded from cost analyses because they lack detailed cost information. Medical costs were defined as the total paid-to-date amount for health care services as of claim closure for closed claims or as of December 2010 for open claims. These costs included professional, facility, and pharmacy costs. Medical costs were adjusted for inflation to December 2008 equivalents using the Consumer Price Index (CPI) for Medical Care, based on the month and year of injury (Bureau of Labor Statistics). Total paid-to-date time-loss compensation costs were measured for each WC claim as of claim closure for closed claims or as of December 2010 for open claims, and were adjusted for inflation using the CPI based on the month and year of injury (Bureau of Labor Statistics).

Descriptive measures from WTR records included age at injury, sex, race/ethnicity, and two expected payer fields. Cause of injury was based on ICD-9-CM external cause of injury codes (E codes) in WTR records and categorized according to CDC recommendations (Centers for Disease Control and Prevention [CDC], 1997). Severity measures included hospital discharge disposition, Injury Severity Score (ISS), maximum head/neck AIS, and length of stay. Hospital discharge disposition was defined as home, transfer/other, or died, based on a patient's final discharge status at the last hospital recorded in the WTR. Individuals in the home group included those who returned home after hospitalization, irrespective of receipt of or need for services at home. Individuals categorized as died before, upon, or after arrival in the hospital. The transfer/other group included those transferred to other acute or long-term care facilities, rehabilitation facilities, or to police custody. ISS is a summary score for traumatic injuries and was categorized as 0–8, 9–15, 16–24, and 25–75, with higher values indicating more severe injuries (Baker, O'Neill, Haddon, & Long, 1974). Maximum head/neck AIS indicates injury severity within the head/neck body region. AIS values range from 1 (minor) to 6 (unsurvivable). Hospital 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.

Data Analysis

Demographic and injury characteristics were described for all WRTBI cases, and by whether they were linked or not to a compensable WC claim. Cost comparisons were limited to linked State Fund compensable closed claims, the subset for which we had complete cost outcome data (self-insured claims were necessarily excluded). Demographics and costs were described by the TBI categories ("isolated TBI" and "TBI with other trauma"). Generalized linear models (GLM) were used to compare costs based on TBI category, which perform well in analyzing right-skewed and over-dispersed cost data (Blough, Madden, & Hornbrook, 1999; Diehr, Yanez, Ash, Hornbrook, & Lin, 1999; Manning, Basu, & Mullahy, 2005). A gamma model with log link was chosen initially, and Box-Cox and modified Park Tests were used to evaluate the appropriateness of this model choice (Manning et al., 2005; Manning & Mullahy, 2001). GLM specification with gamma family and log link was preferable because it does not require retransformation of the data for interpretation and is commonly used in healthcare cost analyses (Manning et al., 2005). Regression models were adjusted for factors that could influence costs, including age at injury, sex, year of injury, and maximum AIS in the head/neck region. Results are reported in terms of cost ratios (CR). We used Stata/SE 11.2 (Stata Corp., College Station, TX) for all analyses.

RESULTS

We identified 273 WRTBI cases that occurred between 1998 and 2008 among Washington State workers aged 16–24. Of the total, 80 (29.3%) were identified as work-related in the WTR but did not link to a compensable WC claim. One hundred ninety-three individuals had TBIs that were linked to a compensable WC claim, of which 159 (82.4%) were identified as work-related in the WTR and 34 (17.6%) were not (Figure 1). The majority of the 34 linked injuries that were not identified as work-related in the WTR were motor vehicle/traffic related injuries. Most demographic and injury characteristics did not differ significantly by linkage status (Table 1). Of the WRTBIs with L&I listed as an expected payer (N=188), 14.4% did not link to a compensable WC claim (p<0.01). Unlinked TBI was more likely to occur in a street/highway and less likely to occur in an industrial site than linked TBI (p=0.04). The distribution of TBI type did not differ substantially across linkage groups. Overall, 38.5% of identified WRTBI cases involved isolated TBI and 61.5% involved TBI with other trauma.

Among all WRTBIs linked to a WC claim (N=193), 151 (78.2%) were closed, State Fund claims that provided complete cost information from L&I and thus were included in comparative cost analyses by TBI type. Isolated TBI constituted 35.8% of this group, and TBI with other trauma made up 64.2% of linked, closed claims involving WRTBI. Age, sex, race, and other demographic characteristics did not significantly vary across TBI type (Table 2). Injury characteristics also did not differ substantially across groups, except for ISS score: individuals with isolated TBI had significantly lower ISS scores than those with TBI with other trauma (p<0.01). As of December 2010, four workers were found by L&I to have total permanent disability and received a pension due to their injuries (1 with isolated TBI and 3 with TBI and other trauma).

Mean unadjusted medical costs among isolated TBI cases did not differ significantly from TBI with other trauma (Table 3). Medical costs averaged $88,307 (median $16,426) for isolated TBI cases, compared to $73,669 (median $41,167) for TBI with other trauma. Mean unadjusted time-loss compensation costs were significantly higher for TBI with other trauma, compared to isolated TBI (p≤0.01). TBI with other trauma cases received an average of $13,734 (median $2,312) in time-loss compensation, nearly 3 times more than isolated TBI (mean $5,834, median $860).

GLM models showed that medical costs for workers with isolated TBI were 56% lower for workers with isolated TBI compared to TBI with other trauma (Cost Ratio, CR 0.44, 95% CI: 0.29–0.68), after adjusting for age, sex, injury year, and maximum head/neck AIS (Table 4). Compared to TBI with other trauma, time-loss compensation costs were 71% lower for isolated TBI cases (CR 0.29, 95% CI: 0.17–0.51), after adjusting for the same covariates.

In order to provide a minimal picture of the magnitude of costs involved in WRTBI among adolescents and young adults, we also calculated total observed costs, including paid-to-date costs for claims still open as of December 2010. Though incomplete because not all costs have yet been paid for open claims, the observed totals provide a lower bound estimate for the costs of WRTBI for workers covered by the State Fund who had injuries reported to the WTR during the 11 years covered by this study. Combining closed and open WC claims for State Fund workers with WRTBI (N=180), medical costs were nearly $19 million and time loss costs were more than $3.6 million (as of December 2010, when data were extracted from L&I). The median combined medical and time-loss compensation cost was approximately $45,000 per injured worker. The median combined per-worker cost was $19,000 for isolated TBI and $68,000 for TBI with other trauma. Total costs associated with isolated TBI were approximately $6.8 million for medical and $700,000 for time loss, compared to TBI with other trauma, for which medical costs were approximately $12.2 million and time loss costs were almost $3.0 million.

DISCUSSION

This study identified 273 WRTBI cases among adolescent and young adult workers aged 16–24 in Washington State from 1998 to 2008 using the WTR. Most were WRTBI with other trauma (61.5%) rather than isolated TBI (38.5%). For injuries linked to a closed WC claim, multivariate analyses showed significantly lower medical and time loss compensation costs among isolated TBI compared to TBI with other trauma. The latter group includes injuries to multiple body regions and likely more complex cases, so it is unsurprising that costs are higher in this group.

From 1998 to 2008, observed total costs among adolescent and young adult workers with a compensable State Fund WC claim for a WRTBI reported to the WTR exceeded $22 million. This represents just a portion of the potential costs for WRTBI among young workers in Washington State. It excludes claims paid by self-insured employers (approximately 30%) and injuries that did not link to a WC claim, was based only on those injuries eligible for and reported to the WTR, and underestimates total costs for the subset of injuries included because some claims were still open and potentially accumulating further costs (presumably the most severe). Nevertheless, it demonstrates the significant cost burden imposed by WRTBI among young workers in Washington State. Cost estimates described in this study apply to young workers and readers should use caution when comparing them to older workers, whose time-loss compensation costs may be higher due to increased earning potential with age.

To our knowledge, previous research on the cost burden of WRTBI is limited to regional studies (Colantonio et al., 2010; Wrona, 2006). An analysis of Washington WC claims from 1994 to 2001 estimated that the median cost of medical, pension, and future costs associated with WRTBI was $61,000 per case for workers of all ages (Wrona, 2006), compared to a median total cost in our study of $45,000 per worker for paid-to-date costs among workers aged 16–24. The two cost estimates are not directly comparable because the previous study included pension and future costs and did not restrict the age range, whereas our study’s estimate was based on paid-to-date medical and time-loss compensation costs for closed claims among young workers. Estimated WRTBI costs in Ontario, Canada appeared much lower than those found in our study (e.g., mean healthcare costs C$2,235), however, this estimate did not include time-loss compensation costs, and their definition of WRTBI included concussions and other mild injuries, which may not have been captured in the WTR data used in our study (Colantonio et al., 2010).

Evaluating outcomes for linked WRTBI cases (those with WTR records and compensable WC claims) does not fully capture outcomes for the population of young workers with WRTBI reported to the WTR. Approximately one-third of WRTBI identified as work-related in the WTR did not link to a compensable WC claim. The work-related indicator in the WTR serves as a convenient, independent identifier of work-related traumatic injuries that do not link to WC claims for various reasons, including employment that is exempt or excluded from WC coverage (State of Washington), employment covered by federal WC programs, injuries that may have been covered by L&I but were not reported, or claims for work-related injuries that were rejected for other reasons (Sears, et al., 2012). For young workers who commonly hold temporary, family, or informal jobs, it is possible that an injury that was classified as work-related in the WTR did not result in a WC claim because WC does not cover employment such as domestic work, newspaper delivery, and work conducted by minor children on family farms (State of Washington). Unsurprisingly, most linked WRTBI had L&I listed as the expected payer; it should be noted, however, that 28% of the cases that did not link to a compensable WC claim also listed L&I as an expected payer. This gap may represent valid work-related injuries that were not linked to a WC claim for the reasons described above.

This study utilized data from two sources, the WTR and WC claims, to identify WRTBI cases among young workers and describe the costs associated with these injuries. The different types of information provided by each data source served as an advantage – it allowed us to identify and describe WRTBI using detailed injury data from the WTR and describe and compare medical and time-loss compensation costs across types of TBI using

WC claims data. Linking WC claims and WTR data overcomes weaknesses in each data source: WC claims lack detailed clinical information and WTR data patient-level variables relevant to work-related injuries, such as occupation and industry. The utility of trauma registries as data sources for occupational injury surveillance could be greatly improved by including these variables, as has been suggested by others (Forst, Hryhorczuk, & Jaros, 1999; Lowry, et al., 2010; Sears, et al., 2012).

This study has some limitations. First, misclassification of work-related injuries in the WTR may have occurred. An injury identified as work-related in the WTR may not have linked to a WC claim because of the reasons described above or because the injury was not actually work-related. Because this study relied on administrative data alone, we were not able to interview patients for clarification and are therefore unable to discern between these two possibilities. Second, this study captures only the relatively severe WRTBI that qualified for inclusion in the WTR. Injuries that do not meet the criteria for inclusion in the WTR (described in Methods), including those treated in clinics or treated at home, were not included in this study. Thus, the number and cost of WRTBI in Washington State during the time period studied should be considered an underestimate of actual numbers and costs. Third, not all eligible traumas are captured by the WTR. In a nationwide survey conducted in 2004 by Mann and colleagues, the WTR trauma manager estimated that the WTR captured about 85% of trauma victims with injuries satisfying registry inclusion criteria (Mann, Guice, Cassidy, Wright, & Koury, 2006). Finally, many costs associated with WRTBI, such as lost productivity and patient out-of-pocket costs were not measured. Therefore, the costs described in this study are an underestimate of societal costs associated with WRTBI among adolescent and young workers.

CONCLUSIONS

The costs of WRTBI reported in this study highlight the impact of WRTBI among young workers in Washington State. Although we were able to measure only a portion of the medical and time-loss costs related to these injuries, they were clearly substantial, well over $22 million for the 11 years covered by this study. The costs described here are also an underestimation of actual societal costs of WRTBI. Injury prevention efforts to reduce the likelihood and severity of WRTBI are warranted, especially in the young worker population, for whom TBI may result in particularly deleterious, long-term consequences. We have demonstrated that the tandem use of multiple data sources (in this case, linking trauma registry records with WC claims) can provide a more comprehensive picture of WRTBI among young workers than a single data source alone. The application of this linked-data source approach extends beyond WRTBI and young workers and holds great potential for future traumatic occupational injury research.

IMPACT ON INDUSTRY

TBI among young workers involves long-term health and psychosocial impacts. In designing prevention strategies, a better understanding of injury characteristics and costs is valuable. Combining trauma registry and workers' compensation (WC) records forms a unique, detailed dataset to investigate work-related injuries, especially among groups not fully captured by WC data.

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Highlights

- We linked trauma registry data and workers' compensation claims.
- Work-related traumatic brain injury (TBI) is a serious problem for young workers.
- Median medical costs ranged from $16,426 to $41,167 for work-related TBI.
- Median costs for compensated time lost from work ranged from $860 to $2,312.
- Using linked data offers enhanced injury information for research and surveillance.

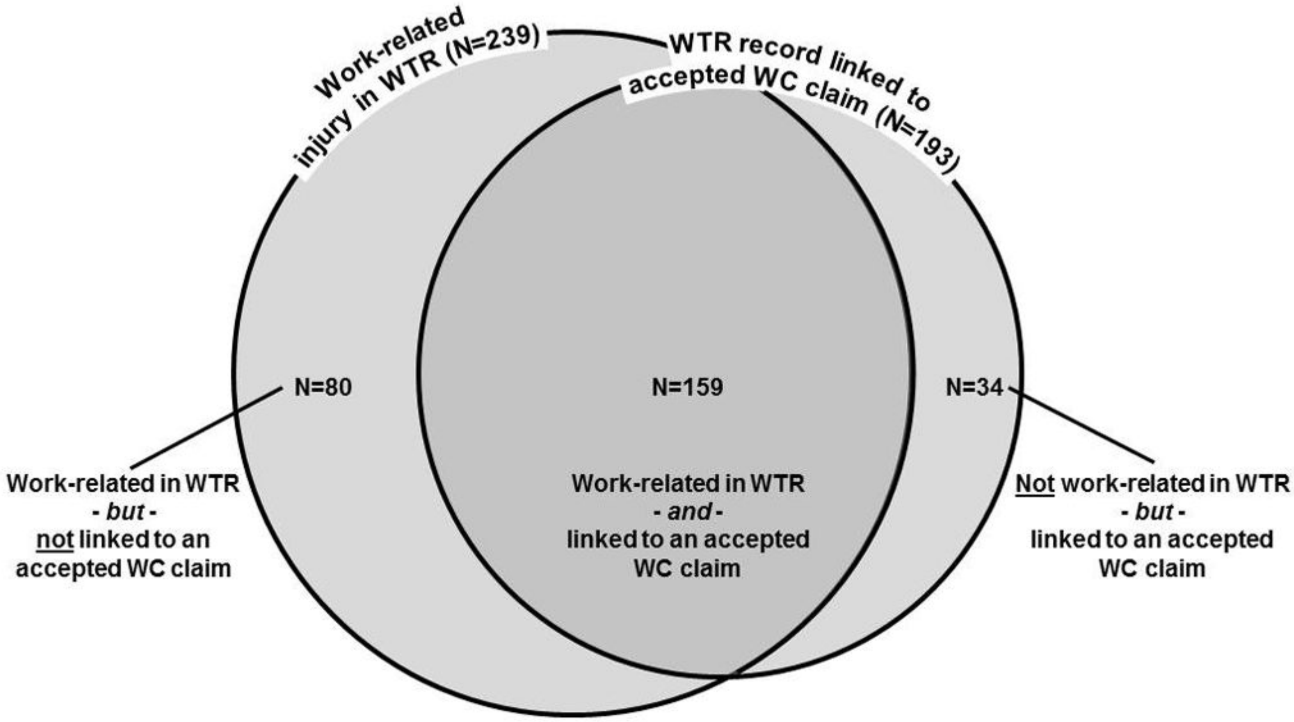

Figure 1.

Identification and linkage of work-related traumatic brain injuries from WTR records for injured persons aged 16–24 between 1998 and 2008. There were 273 that were either work-related in WTR or accepted WC claim linked to WTR record.

Abbreviations: TBI, traumatic brain injury; WC, workers' compensation; WRTBI, work-related traumatic brain injury; WTR, Washington Trauma Registry

Table 1

Patient demographic and injury characteristics among work-related traumatic brain injuries reported in the Washington Trauma Registry.

	Unlinked TBI	Linked TBI	All TBI	Sig
Number of workers	80	193	273	
Age (years, at ED arrival)				0.06
16–18	18 (22.5)	24 (12.4)	42 (15.4)	
19–21	31 (38.8)	70 (36.3)	101 (37.0)	
22–24	31 (38.8)	99 (51.3)	130 (47.6)	
Sex				0.83
Male	70 (87.5)	167 (86.5)	237 (86.6)	
Female	10 (12.5)	26 (13.5)	36 (13.2)	
Race/ethnicity				0.09
White	50 (62.5)	127 (65.8)	177 (64.8)	
Latino/Hispanic (any race)	20 (25.0)	31 (16.1)	51 (18.7)	
Other	5 (6.3)	7 (3.6)	12 (4.4)	
Missing	5 (6.3)	28 (14.5)	33 (12.1)	
Payer				<0.001
L&I only	22 (27.5)	146 (75.7)	168 (61.5)	
L&I and other insurance	5 (6.3)	15 (7.8)	20 (7.3)	
Other government or private insurance	37 (46.3)	18 (9.3)	55 (20.2)	
None (self pay, charity)	13 (16.3)	4 (2.1)	17 (6.2)	
Missing (no payer information)	3 (3.8)	10 (5.2)	13 (4.8)	
Place of injury				0.04
Industrial	28 (35.0)	96 (49.7)	124 (45.4)	
Street/highway	25 (31.3)	36 (18.7)	61 (22.3)	
Other	23 (28.8)	45 (23.3)	68 (24.9)	
Unspecified/missing	4 (5.0)	16 (8.3)	20 (7.3)	
Cause of injury				0.11
Falls	26 (32.5)	89 (46.1)	115 (42.1)	
Motor vehicle traffic	23 (28.8)	39 (20.2)	62 (22.7)	
Struck by/against object	18 (22.5)	27 (14.0)	45 (16.5)	
Machinery	1 (1.3)	6 (3.1)	7 (2.6)	
Other	12 (15.0)	32 (16.6)	44 (16.1)	
Hospital discharge disposition				0.44
Home	56 (70.0)	118 (61.1)	174 (63.7)	
Transfer/other	19 (23.8)	61 (31.6)	80 (29.3)	
Expired	5 (6.3)	12 (6.2)	17 (6.2)	
Missing	0 (0)	2 (1.0)	2 (0.7)	
Injury severity score (ISS)				0.59
0–8	15 (18.8)	29 (15.0)	44 (16.1)	
9–15	21 (26.3)	61 (31.6)	82 (30.0)	

	Unlinked TBI	Linked TBI	All TBI	Sig
16–24	25 (31.3)	50 (25.9)	75 (27.5)	
25–75	19 (23.8)	53 (27.5)	72 (26.4)	
Maximum Abbreviated Injury Score (AIS) for Head/Neck				0.96
1–2	20 (25.0)	54 (28.0)	74 (27.1)	
3	26 (32.5)	62 (32.1)	88 (32.2)	
4	20 (25.0)	43 (22.3)	63 (23.1)	
5–6	12 (15.0)	27 (14.0)	39 (14.3)	
Missing	2 (2.5)	7 (3.6)	9 (3.3)	
Length of stay (LOS), days				0.17
0–1	26 (32.5)	43 (22.3)	69 (25.3)	
2	6 (7.5)	28 (14.5)	34 (12.5)	
3–6	28 (35.0)	55 (28.5)	83 (30.4)	
7–13	10 (12.5)	36 (18.7)	46 (16.7)	
≥ 14	10 (12.5)	29 (15.0)	39 (14.3)	
Missing	0 (0)	2 (1.0)	2 (0.7)	
TBI type				0.15
Isolated TBI	36 (45.0)	69 (35.8)	105 (38.5)	
TBI with other trauma	44 (55.0)	124 (64.3)	168 (61.5)	

Abbreviations: ED, emergency department; SD, standard deviation; TBI, traumatic brain injury; WC, workers' compensation; WRTBI, work-related traumatic brain injury; WTR, Washington Trauma Registry.

Frequency counts do not always sum to total because of missing responses or rounding.

Unless otherwise indicated, values are N (%) and significance values indicate results from χ^2 tests.

Table 2

Patient demographic and injury characteristics by TBI type among WRTBI reported in WTR and linked to a closed, compensable State Fund WC claim (N=151).

	Isolated TBI	TBI with other trauma	All TBI	Sig
Number of workers	54	97	151	
Age (years, at ED arrival)				0.40
16–18	5 (9.3)	15 (15.9)	20 (13.3)	
19–21	18 (33.3)	36 (37.1)	54 (35.8)	
22–24	31 (57.4)	46 (47.4)	77 (60.0)	
Sex				0.22
Male	44 (81.5)	86 (88.7)	130 (86.1)	
Female	10 (18.5)	11 (11.3)	21 (13.9)	
Race/ethnicity				0.87
White	34 (63.0)	64 (66.0)	98 (64.9)	
Latino/Hispanic (any race)	8 (14.8)	16 (16.5)	24 (15.9)	
Other	2 (3.7)	4 (4.1)	6 (4.0)	
Missing	10 (18.5)	13 (13.4)	23 (15.2)	
Payer				0.12
L&I only	41 (75.9)	76 (78.4)	117 (77.5)	
L&I and other insurance	5 (9.3)	8 (8.3)	13 (8.6)	
Other government or private insurance	4 (7.4)	6 (6.2)	10 (6.6)	
None (self pay, charity)	3 (5.6)	0 (0)	3 (2.0)	
Missing	1 (1.9)	7 (7.2)	8 (5.3)	
Place of injury				0.73
Industrial	29 (53.7)	46 (47.4)	75 (49.7)	
Street/Highway	11 (20.4)	19 (19.6)	30 (19.9)	
Other specified	11 (20.4)	22 (22.7)	33 (21.9)	
Unspecified/missing	3 (5.6)	10 (10.3)	13 (8.6)	
Cause of injury				0.29
Falls	22 (40.7)	51 (52.6)	73 (48.3)	
Motor vehicle traffic	10 (18.5)	22 (22.7)	32 (21.2)	
Struck by/against object	10 (18.5)	8 (8.3)	18 (11.9)	
Machinery	2 (3.7)	3 (3.1)	5 (3.3)	
Other	10 (18.5)	13 (13.4)	23 (15.2)	
Hospital discharge disposition				0.12
Home	37 (68.5)	61 (62.9)	98 (64.9)	
Transfer/other	13 (24.1)	26 (26.8)	39 (25.8)	
Expired	2 (3.7)	10 (10.3)	12 (8.0)	
Missing	2 (3.7)	0	2 (1.3)	
Injury severity score (ISS)				<0.001
0–8	17 (31.5)	10 (10.3)	27 (17.9)	
9–15	22 (40.7)	30 (30.9)	52 (34.4)	

	Isolated TBI	TBI with other trauma	All TBI	Sig
16–24	10 (18.5)	26 (26.8)	36 (23.8)	
25–75	5 (9.3)	31 (32.0)	36 (23.8)	0.69
Maximum Abbreviated Injury Score (AIS) for Head/Neck				
1–2	32 (33.0)	15 (27.8)	47 (31.1)	
3	30 (30.9)	22 (40.7)	52 (34.4)	
4	16 (16.5)	10 (18.5)	26 (17.2)	
5–6	14 (14.4)	5 (9.3)	19 (12.6)	
Missing	5 (5.2)	2 (3.7)	7 (4.6)	0.05
Length of stay (LOS), days				
0–1	18 (33.3)	19 (19.6)	37 (24.5)	
2	9 (16.7)	15 (15.5)	24 (15.9)	
3–6	13 (24.1)	31 (32.0)	44 (29.2)	
7–13	10 (18.5)	17 (17.5)	27 (17.9)	
≥ 14	2 (3.7)	15 (15.5)	17 (11.3)	
Missing	2 (3.7)	0 (0)	2 (1.3)	

Abbreviations: ED, emergency department; SD, standard deviation; TBI, traumatic brain injury; WC, workers' compensation; WRTBI, work-related traumatic brain injury; WTR, Washington Trauma Registry.

Frequency counts do not always sum to total because of missing responses or rounding.

Unless otherwise indicated, values are N (%) and significance values indicate results from χ^2 tests.

Table 3

Costs for occupational trauma by TBI type, for WRTBI reported in WTR and linked to a closed, compensable State Fund WC claim (N=151).

	Isolated TBI	TBI with other trauma	Sig
Number of workers	54	97	
Medical costs[a,b]			
Mean (SE)	$ 88,307 (61,118)	$ 73,669 (9,719)	0.81
Median (IQR)	16,426 (23,914)	41,167 (84,635)	
Time-loss compensation[a,c]			
Mean (SE)	5,834 (1,722)	13,732 (2,312)	<0.01
Median (IQR)	860 (5,515)	4,677 (12,491)	

Abbreviations: IQR, inter-quartile range; SE, standard error; TBI, traumatic brain injury; WC, workers' compensation; WRTBI, work-related traumatic brain injury; WTR, Washington Trauma Registry.

Significance indicates p-value for comparison of mean costs t-tests across TBI types.

[a]Mean and median costs are in US dollars and include all workers, including non-users and those with zero costs.

[b]Medical costs refer to total paid-to-date professional, facility, and pharmacy costs from closed claims. Medical costs are inflation adjusted to December 2008 equivalents using the Medical Consumer Price Index (CPI), based on the month and year of injury.

[c]Time-loss compensation costs refer to total paid-to-date compensation for time lost from work due to injury and are inflation adjusted to December 2008 equivalents using the CPI, based on the month and year of injury.

Table 4

Cost ratio comparisons by TBI type for WRTBI reported in WTR and linked to a closed, compensable State Fund WC claim (N=151).

	Medical costs[a]		Time-loss compensation[b]	
	Unadjusted CR (95% CI)	**Adjusted CR (95% CI)**	**Unadjusted CR (95% CI)**	**Adjusted CR (95% CI)**
TBI with other trauma	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
Isolated TBI	1.20 (0.30, 4.73)	0.44 (0.29, 0.68)	0.42 (0.22, 0.82)	0.29 (0.17, 0.51)

Adjusted, multivariable models include the following covariates: age, sex, year of injury, and maximum AIS for head/neck.

Abbreviations: CI, confidence interval; CR, cost ratio; TBI, traumatic brain injury; WC, workers' compensation; WRTBI, work-related traumatic brain injury; WTR, Washington Trauma Registry.

Cost ratios compare TBI with other trauma to isolated TBI.

[a]Medical costs refer to total paid-to-date professional, facility, and pharmacy costs from closed claims. Medical costs are inflation adjusted to December 2008 equivalents using the Medical Consumer Price Index (CPI), based on the month and year of injury.

[b]Time-loss compensation costs refer to total paid-to-date compensation for time lost from work due to injury and are inflation adjusted to December 2008 equivalents using the CPI, based on the month and year of injury.