Work-Related Concussion Surveillance

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Background *The goal of this study was to use multiple state-based data sources (emergency department [ED] visits, hospital discharge [HD] data, and workers' compensation [WC] data) to estimate the 2011 work-related concussion injury rate in Kentucky.*

Methods *Deterministic data linkages between the 2011 WC data and ED/HD data were performed. Annual crude rates of work-related concussions per 100,000 employed civilians age 16 years or older were reported.*

Results *Using the three data sources, the 2011 work-related concussion crude rate was 31.8/100,000, higher for men (38.8/100,000) than for women (24.1/100,000). The use of WC data alone resulted in an estimated rate of only 11.7/100,000. ED data utilization alone resulted in a rate of 21.7/100,000.*

Conclusion *This study's primary recommendation is to use WC, ED, and HD data on a routine basis as part of multiple data source surveillance for work-related concussion injuries.* Am. J. Ind. Med. 00:XX–XX, 2014.

KEY WORDS: work-related; concussion; surveillance; multiple data sources; workers' compensation; emergency department visits; hospitalizations

INTRODUCTION

Concussion is defined as a traumatically induced transient disturbance of brain function and involves a complex pathophysiological process [Harmon et al., 2013]. A concussion can be caused by a bump, blow, or jolt to the head, and can also occur from a fall or a blow to the body that causes the head to move rapidly back and forth [CDC, 2010]. Although concussions are usually not life-threatening, physical, cognitive, and emotional symptoms can last for days or even weeks, and make it difficult for the injured person to perform daily activities, increasing the probability for a new injury. An estimated 408,484 concussions were treated in U.S. hospital emergency departments (EDs) in 2009, at an annual rate of 133.1 injured persons per 100,000 U.S. population [Slavova et al., 2012]. Youths 10–18 years of age had the highest rate at 374.8/100,000. Many more concussions are treated by primary care physicians and athletic trainers, but often the concussion symptoms are unrecognized, especially if there is no loss of consciousness, or if medical help is not sought. In a survey among ED patients, 88.6% of the respondents who experienced concussion injuries reported that they didn't recognize that they had suffered a concussion [Delaney et al., 2005].

Most of the current concussion research, education, legislation, and prevention activities are primarily focused on sport-related concussions [Wiebe et al., 2011; Harmon et al., 2013]. In recent years, many states passed student-athlete concussion laws regulating the necessary actions before an athlete with a suspected concussion may return to play, and usually requiring concussion education for coaches, parents, and athletes [Adler and Herring, 2011; CDC, 2014a,b].

There is a paucity of current research focusing only on the epidemiology of occupational concussions, although recently there has been an increased awareness of concussions among professional football players [Pieroth and Hanks, 2014] and

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military personnel [Cogan, 2014], and on return-to-work issues [Pieroth, 2012; Cancelliere et al., 2014]. There are several epidemiological studies on occupational traumatic brain injuries (TBIs) and mild TBIs (mTBIs) [Wrona, 2006; Kristman et al., 2008; Colantonio et al., 2009; Wei et al., 2010; Chang et al., 2011; Liu et al., 2011; Tiesman et al., 2011] and although concussions and mTBIs are relatively interchangeable, direct comparison may not be appropriate due to some methodological issues [Carroll et al., 2004].

According to the Bureau of Labor Statistics (BLS) Survey of Occupational Injuries and Illnesses (SOII) [BLS, 2014a] in 2010 in the United States, there were 5,870 occupational concussions involving days away from work in private industry (21% were in the service occupations, and 20% in transportation and material moving occupations). The annual incidence rate for nonfatal occupational concussions with days away from work was 7/100,000 full-time workers by private industry. The highest incidence rates were in transportation and material moving (17/100,000), farming, fishing and forestry (13/100,000), and installation maintenance and repair occupations (11/100,000). The median days lost from work due to occupational concussion injury in 2010 was 6 days for U.S. workers in private industry.

Several studies suggest that the SOII significantly underestimates the incidence of work-related injuries and illnesses and suggest multiple reasons for incompleteness [Azaroff et al., 2002; Rosenman et al., 2006; Boden and Ozonoff, 2008; Boden, 2014]. Other studies suggest that the SOII undercount is moderate, when accounting for the confounding effects of legal and database issues [Oleinick and Zaidman, 2010]. Ruser postulated that methodological issues, data timeliness, reporting incentives, and data system differences contribute to that SOII undercount [Ruser, 2008]. Researchers argued that a multiple data source system could improve the estimation of the burden of workplace injuries and illnesses, although the implementation of such a system for nonfatal conditions at the national level may not be feasible and justified due to the large volume of cases, lack of comparability of data sources across states, differences in the state workers' compensation (WC) laws, variations in state laws governing data access and data sharing among agencies, and timeliness of data [Ruser, 2008; Davis et al., 2014]. Despite challenges at the national level, Davis et al. believed that multisource surveillance is extremely useful at the state level to inform intervention activities [Davis et al., 2014]. Harrison and Flattery concluded that the adoption of electronic data systems for hospital discharge (HD), ED, ambulatory surgery, and workers' claims, improves the ability of state and federal agencies to perform coordinated and timely surveillance that more closely approximates the true nature and extent of workplace mortality and morbidity [Harrison and Flattery, 2010].

We hypothesized that due to the nature, symptoms, and treatment of concussion injuries, the use of multiple data sources for workplace concussion surveillance is needed because either WC data or BLS SOII data alone would significantly underestimate the incidence of workplace concussion injuries in our state. Concussions that require medical treatment but did not result in days away from work may not be reported to WC but could be captured with ED visits or other data sources. The goal of this study was to use multiple state-based data sources (ED visits, HD data, and WC first report of injury [FROI] data) to estimate the annual work-related concussion injury frequencies and rates in Kentucky and pilot a comprehensive multiple data source surveillance system for occupational concussions in the state.

MATERIALS AND METHODS

This study was part of the Kentucky Occupational Safety and Health Surveillance research program, which was approved by the University of Kentucky Institutional Review Board.

Kentucky inpatient HD uniform billing electronic records and ED visit records were used to supplement the FROI data. The Kentucky HD and ED visit data systems contain a principal diagnosis, up to 24 secondary diagnoses, and up to three designated external-cause-of-injury (E-code) fields coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). Work-related concussion injuries that were treated in Kentucky EDs or hospital facilities in 2011 were identified as discharges with a principal or a secondary ICD-9-CM diagnosis code of 850 (Concussion) and with WC listed as an expected payer. ED and HD administrative claim data are collected for billing purposes and there is no specific indicator on the work-relatedness of the injury available in Kentucky data. The expected payer source of "WC" is used as a proxy for work-relatedness.

ED/HD data did not contain personal identifiers such as names, addresses, or social security numbers. Follow-up visits for the same injury (to the same or a different ED facility) were identified based on patient's date of birth, gender, race, ethnicity, county of residence, zip code of residence, and diagnosis codes. The classification of injuries by cause and intent was based on E-code [CDC, 2014c].

The Kentucky Department of Workers' Claims (KDWC) FROI database was used to identify work-related concussion injuries with injury date in 2011. A "concussion injury" was identified in KDWC data by: (i) the nature of injury listed as "concussion" (nature code = 07) according to Workers' Compensation Insurance Organization (WCIO) injury description codes [WCIO, 2014] used by the KDWC; or (ii) a case narrative text search for the mention of "concussion." ICD-9-CM diagnosis codes are not available in the FROI database, so the analysis of WCIO codes is the closest proxy for concussion diagnoses.

Deterministic data linkages between the WC data and ED/HD concussion records were performed using the following

TABLE I. Work-Related Concussion Injuries by Data Source, Kentucky, 2011

	Data source	Number of injuries	Records identifiable as concussions from the data source alone?	Concussion case identified by:	Added new records
1.	WC	220	Yes	"Concussion" listed as nature of injury or mentioned in the injury description field	220
2.	WC	113	No	Identified through linkage with the ED records that listed ICD-9-CM concussion diagnoses	113
3.	WC	6	No	Identified through linkage with the HD records that listed ICD-9-CM concussion diagnoses	6
4.	ED	407	Yes	Any diagnosis of concussion (ICD-9-CM diagnosis code 850)	248
5.	HD	16	Yes	Any diagnosis of concussion (ICD-9-CM diagnosis code 850)	9
Total number of work-related concussions from the three surveillance sources					596

variables: date of birth, gender, county of residency, and date of injury/date of admission. A strict match on the date of birth and gender was enforced, up to a week difference between the date of injury and the date of the ED visit, and possible discrepancies on county of residency were allowed and reviewed manually for plausibility.

Annual crude rates, gender-specific rates, and age-specific rates of work-related concussion injuries per 100,000 employed civilians age 16 years or older were reported. The denominators were obtained from the Current Population Survey, utilizing the US Census Bureau program DataFerrett [DataFerrett, 2014].

Statistical analysis and data management were performed using statistical software SAS® Version 9.3 [SAS, 2010].

RESULTS

The use of multiple surveillance sources identified a combined total of 596 work-related concussions occurring in Kentucky in 2011, at an annual rate of 31.8 concussions per 100,000 employed civilians 16 years or older. The use of WC data alone resulted in an estimated rate of only 11.7/100,000; ED data utilization alone resulted in a rate of 21.7/100,000.

Using the three data sources (WC, ED, and HD datasets), and combining the results from the linkages (Table I), we identified a total of 596 work-related concussions in Kentucky, 2011. There were 220 FROIs filed with the KDWC for concussions in 2011. Of those, 188 concussions were coded with a nature code of "concussion"; 32 injuries were coded with other nature codes (e.g., 19 were coded as "multiple physical injuries"; 5 "contusions," 2 "fractures," and 2 "lacerations"), but the text description of the injury contained the word "concussion."

In 2011, there were 412 concussion-related ED visits in Kentucky with WC as the expected payer. Follow-up visits were excluded from the analysis (n = 5) resulting in a total of 407 patients treated in Kentucky EDs for a work-related concussion. The majority of the concussion-related ED visits had "concussion" listed as a principal diagnosis (76.4%). The remaining patients had a secondary diagnosis of concussion with a principal diagnosis of "other open wound of head" (5.7%), "sprains and strains on neck" (3.9%), "contusion of face, scalp, neck" (3.4%), and other (data not shown).

There were 16 inpatient hospitalizations billed to WC, listing concussion as a principal (n = 5) or a secondary (n = 11) diagnosis.

The linkage between the WC data and the ED visits data resulted in only 46 matches coded as concussions in both datasets (Fig. 1). Only 46 (11.3%) of the workers who were treated in the ED for work-related concussions submitted a FROI to the KDWC that specifically coded the work-related injury as a concussion. One hundred thirteen work-related

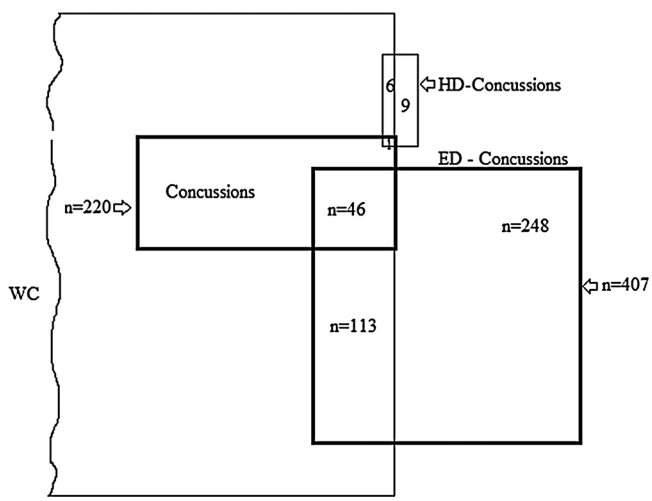

FIGURE 1. State data sources for work-related concussion surveillance, Kentucky 2011.

WC, workers' compensation data; HD, hospital discharge data; ED, emergency department discharge data.

concussion ED visits (Fig. 1) were matched to the set of FROI, but the information recorded in the WC data did not list concussion among the sustained injuries. A review of the 113 WC records showed that the majority of these workers experienced multiple injuries including injuries more severe than a concussion, which was reflected in the nature of the injury field on the WC record. For example, 34 of the 113 records (30.1%) listed nature "contusion," 24 injuries (21.2%) had nature "multiple physical injuries," 12 (10.6%) with nature "laceration," 11 (9.7%) with nature "fracture," and so on. Reviewing the information on injured body region coded on these 113 FROI records, we found that 35 (31%) of them were coded as cases with "multiple body parts" injured, 16 (14.2%) listed "multiple head injuries," 22 (19.5%) were coded as "skull injuries," 12 (10.6%) were coded as "other facial soft tissue," etc. Of the 248 worker concussions treated in the EDs and billed to WC but not reported to KDWC, 33% had some loss of consciousness.

Of the 16 concussion hospitalizations, seven were linked to FROI records. Only one of the seven WC records listed concussion as the nature of injury. The remaining six WC records described injuries affecting multiple body parts and did not mention concussion in particular.

The annual crude rate for work-related concussions per 100,000 employed civilians 16 years or older was 31.8/100,000, higher for men (38.8/100,000) than for women (24.1/100,000) (Table II). The majority of the concussed workers were men (n = 379; 63.6%). The highest concussion rate was among the youngest workers, aged 16–24 years (43.9/100,000) (Table II). The median age of the concussed workers was 39 years. The highest number of concussions (n = 139) was among the 35–44-year-old age group The highest concussion rates were due to being struck by or against an object or person (12.9/100,000), falls (10.7/100,000), and motor vehicle collisions (3.1/100,000). Gender specific rates by cause-of-injury followed the same order. Males experienced concussion injuries due to struck by/against injuries at a rate of 14.7/100,000, due to falls at a rate of 12.8/100,000, and due to motor vehicle collisions at a rate of 4.7/100,000 (data not shown). Work-related concussion rates among females were 11/100,000 due to struck by/against, 8.9/100,000 due to falls, and 1.6/100,000 due to motor vehicle crashes (data not shown).

Information on industry was available only for the 339 cases reported to the KDWC. Therefore, rates by industry would be a significant underestimation given the fact that 257 cases from ED and hospital data sources did not list an industry category. Limiting the information to WC data only, the majority of the cases were in services industry (n = 104; 30.7% of the WC cases), transportation/public utilities (n = 50; 14.7% of the WC cases), whole sale and retail (n = 50; 14.7%), and manufacturing (n = 32; 9.4%) (data not shown).

About one-third of the concussions treated in the ED were described as concussions with a loss of consciousness (0.5% with loss of consciousness between 1 and 24 hr; 10.8% with loss of consciousness of 30 min or less; 21.6% with loss of consciousness of unspecified duration) (data not shown). Loss of consciousness is not coded in the WC data but "loss of consciousness" or "passing out" was mentioned in the text description of nine of the WC records that were not matched to ED records.

TABLE II. Characteristics of Work-Related Concussions in Kentucky, 2011

Characteristics of work-related concussions in Kentucky	Number	%	Rate per 100,000 employed civilians 16 years or older
Gender			
Males	379	63.6	38.8
Females	217	36.4	24.1
Age			
16–24	109	18.3	43.9
25–34	132	22.1	32.3
35–44	139	23.3	35.0
45–54	117	19.6	25.5
55–64	79	13.3	28.1
65+	20	3.4	24.6
Cause of injury[a]			
Motor vehicle collision	59	10.7	3.1
Fall	200	36.2	10.7
Struck by/against	242	43.8	12.9
Other	51	9.2	2.7
Total	596	100.0	31.8

[a]Missing information on cause of injury for 44 cases.

DISCUSSION

This is the first study, to the best of our knowledge that identifies work-related concussions using three data sources. The incidence of concussions recorded in WC data was underestimated by 50% when the "nature of injury" and "description of injury" fields were limited to "concussion." WC data alone identified 220 concussion cases but the linkage of the WC database with ED and HD work-related concussion cases identified an additional 119 cases reported to WC but not recorded as concussions in WC. The majority (n = 248; 61%) of the workers who were treated in EDs for concussions were not matched to any WC records and likely did not submit a FROI with the KDWC. Of the unmatched concussion ED visits, 32 listed the patient's state of residency as out-of-state, so it is possible that the workers carried WC insurance from another state. It is possible that some of the concussed workers did not report the injury to the employer or did not miss more than one day from work. According to

the Workers' Compensation Act, Chapter 342 of the Kentucky Revised Statutes (KRS 342.038), a report of injury must be filed with KDWC if an employee misses more than one day of work due to an injury. Some states require more lost workdays before a report for injury is filed with WC system (e.g., 5 days in Massachusetts [Davis, 2014], 7 days in Michigan [MWCA, 2014]).

The benefit of utilizing state-based data for concussion surveillance is apparent when comparing with the BLS SOII data. According to BLS in 2011 in Kentucky, there were 70 nonfatal cases with nature of injury "concussion" that involved days away from work; an annual rate of 5/100,000 full time workers. The reported median days lost was 2 days. For comparison, the state WC data included 188 first reports of injuries with nature "concussion," more than twice the cases reported by BLS SOII [BLS, 2014b].

About 64% of the 2011 work-place concussion injuries captured by the multisource data were among men; a result comparable to the two-thirds of men who experienced concussions according to 2011 SOII data for Kentucky [BLS, 2014b]. Kristman et al. reported similar results, 65% of Ontario's occupational concussions in 1998 were experienced by males [Kristman et al., 2008]. Our results were also in agreement with the findings by Kristman et al. that the highest percent concussions were for workers in service, transportation, and manufacturing.

Limitations of this study include the lack of data for Kentucky workers treated in EDs or hospitals in bordering states, the lack of data for workers treated in other settings (e.g., first aid office at the work place, urgent treatment centers, or primary care physician offices), and the lack of any medical treatment.

Some may consider the use of deterministic linkage as a limitation of this study. As the purpose of this research was to evaluate the benefit of utilizing multiple data sources for concussion surveillance, we wanted to be conservative in our judgment about whether two records from different sources referred to the same case and decreased the possibility for falsely matched records. The WC, ED, and HD work-related concussion data sets were relatively small, limited to 1 year of data, utilized standardized coding, and had established quality control procedures. The critical data fields used in the deterministic linkage of the work-related concussion datasets had 0% missing values. The results of this study show that even a conservative exact match obtained through deterministic linkage reveals the benefit of combining multiple data sources to better understand the epidemiology of concussion injuries experienced at workplaces. In order to make inference about the incidence of work-related concussion injuries in the state and to conduct population-based analysis, a probabilistic data linkage [Clark, 2004] could be performed that accounts for possible typos, misspellings, inaccuracies, and incompleteness within the administrative claim records.

This study provides one example of how a single data source surveillance targeting concussion injuries would undercount the incidents due to the limited specificity and completeness of the information recorded in a single surveillance data collection system, and due to limitations of the inclusion criteria for a particular data system. The WC database has only one code/field for the nature of the injury and, as expected, many concussion injuries were "hidden" under "multiple physical injuries," or the more severe co-existing injuries (like fracture or laceration) were coded instead in the nature of injury field. Similar results were reported by Kristman et al. who found that many concussions may be missed by using only the "concussion code" and that restricting the enumeration to specific nature of injury and part of body codes in WC databases can underestimate the prevalence of mTBIs in the working population. A narrative text search in WC records and linkage of WC data with ED/HD concussion records improved the identification of concussion cases in the WC data set. The Kentucky ED and HD datasets allow up to 25 ICD-9-CM diagnosis codes for describing the nature of the injury and the body part affected. Therefore, a concussion injury could be identified by ICD-9-CM diagnosis code 850 even when other more severe injuries are listed as co-existing diagnoses. Work-related concussion injuries may be subject to significant undercounting by WC systems in states where the employer is required to file a first report of injury after several lost workdays due to the injury. According to BLS SOII data, the median days lost due to concussions in the private industry nationwide was 4 days in 2011, and 5 days in 2012 [BLS, 2014b]. Therefore, the inclusion of ED and hospital data is important for capturing work-related concussion injuries that would otherwise not meet state WC reporting requirements. Using only one surveillance source can lead to significant underestimation of the extent and burden of work-related concussions.

The use of WC, ED, and HD data on a routine basis as part of multiple data source surveillance for work-related concussion injuries is recommended.

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