The Epidemiology of Fatal Occupational Traumatic Brain Injury in the U.S.

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Background: Although traumatic brain injury (TBI) is one of the leading causes of death and disability in the U.S., work-related TBI has not been well documented.

Purpose: The aim of this study was to describe the epidemiologic characteristics and temporal trends of fatal occupational TBI in the U.S between 2003 and 2008.

Methods: A cross-sectional analysis of the Census of Fatal Occupational Injury database was performed. Both the Occupational Injury and Illness Classification System nature of injury codes and body part codes were used to define TBIs. Fatality rates were calculated using denominators derived from the Current Population Survey. Fatality rates were compared among industries, cause of death, and demographics with rate ratios (RRs) and 95% CIs. Poisson regression was used to assess trends in fatality rates. Data were analyzed in 2009–2010.

Results: Nearly 7300 occupational TBI deaths occurred between 2003 and 2008, for an average fatality rate of 0.8 per 100,000 workers per year. The leading causes of occupational TBI death were as follows: motor vehicle (31%); falls (29%); assaults and violent acts (20%); and contact with objects/equipment (18%). Fatality rates were 15 times higher in men compared with women (RR=15, 95% CI=13.7, 16.3). Workers aged ≥65 years experienced the highest TBI fatality rate of all age groups (2.5 per 100,000 per year). Construction, transportation, and agriculture/forestry/fishing industries recorded nearly half of all TBI fatalities (n=1828, n=825, n=761, respectively). Occupational TBI death rates declined 23% over the 6-year period ($p<0.0001$).

Conclusions: This study provides the first national profile of fatal TBIs occurring in the U.S. workplace. Prevention efforts should be directed at those industries with the highest frequency and/or highest risk. The construction industry had the highest number of TBIs, and the agriculture, forestry, and fishing industry had the highest rates. Additionally, workers aged >65 years in all industries would be a good target for future prevention efforts.

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Introduction

Traumatic brain injury (TBI) is a leading cause of death and disability in the U.S. Every year in the U.S., 1.4 million people sustain a TBI. Of these people, more than a million people are treated and released from emergency departments, nearly 250,000 are hospitalized, and 50,000 die as a result of their injury.[1] Given the number of individuals affected, the seriousness of the long-term consequences, and the substantial costs associated with TBI, efforts to better understand and prevent these injuries have increased in recent years.[2,3] Although published work on TBI has had a variety of foci, few reports focus on TBI occurring at the workplace. Previous reports of occupational TBI have focused on a single state or were published 25 years ago and could benefit from an updated analysis.[4–7]

Although the epidemiology of both fatal and nonfatal occupational TBI occurring in Canada has recently been described, to our knowledge, there is no published national report of occupational TBIs occurring in the U.S.[8–11] Reasons for the scarcity of research in occupational TBI include the lack of a case definition within current occupational injury coding systems and difficulty separating occupational from non-occupational events using hospital discharge records. In addition, defining mild and moderate (nonfatal) TBIs using secondary data,

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regardless of the work-relatedness of the event, can be challenging. Given that fatal and nonfatal injuries often have similar epidemiologic patterns, groups found to be at an increased risk for fatal TBI could also be at risk for nonfatal events. Reducing nonfatal TBIs remains important because of the serious consequences faced by those who sustain one. Therefore, the primary purpose of the current study was to identify groups at highest risk for fatal work-related TBI and examine trends in the major external causes of these injuries. Although this article specifically focuses on fatal events, its impact could be far more widespread.

Methods

Data Sources

Occupational TBI fatalities occurring between 2003 and 2008 were obtained from the Census of Fatal Occupational Injury (CFOI), a database maintained by the Bureau of Labor Statistics (BLS) in 2009. BLS defines fatal work-related injury as those fatalities occurring to non-institutionalized people, working at the time of the incident, and on the premises of their employer. The CFOI includes information on all fatal work-related injuries occurring in all 50 states and the District of Columbia from federal, state, and local sources, such as death certificates, workers' compensation reports, Occupational Safety and Health Administration investigation reports, medical examiner reports, news media, and police reports.

To calculate fatality rates, the number of annual workers was extracted from the BLS Current Population Survey (CPS). The CPS is a monthly survey of approximately 50,000 civilian, non-institutionalized residents aged ≥15 years that provides information on employment, occupation, industry, and other work-related characteristics.[12] Because of this restriction, the present study excluded TBI fatalities occurring to those aged <15 years for rate calculations. Because the CPS excludes military personnel and the CFOI includes military deaths only if the event occurred within the U.S., work-related TBI fatality rates presented here are applicable to civilians.

Variable Definitions

The CFOI variables are categorized according to the Occupational Injury and Illness Classification System codes (OIICS).[13] This classification system provides detailed codes for the nature of injury, body part affected, source and secondary source of injury, and injury event. Because no current guidelines exist for case ascertainment of TBIs using the OIICS, the authors developed a case definition based on the current CDC definition of TBI and BLS expertise.[13] For the current study, the following nature of injury codes were used to define TBI: 060 (intracranial injuries, unspecified); 061 (cerebral hemorrhages); 062 (concussions); 068 (multiple intracranial injuries); and 069 (intracranial injuries, not elsewhere classified). A combination of the body part affected and nature of injury codes were used to obtain all firearm-related TBIs (n=1245). These were included if the body part code equaled 00 (head, unspecified); 01 (cranial region, including skull); or 08 (multiple head locations) and the nature of injury code equaled 036 (gunshot wounds).

After ascertainment of the TBI fatalities, steps were taken to validate the case definition. Firstly, all TBIs coded as '061' (cerebral hemorrhage) were examined to ensure that the TBI did not occur as a result of a physiologic hemorrhagic stroke. Using the narrative text fields, it was determined that the 244 cerebral hemorrhages were caused by a traumatic injury event and unrelated to hemorrhagic stroke. Second, all fatalities where nature of injury was 090 (other traumatic injuries and disorders) and body part injured was 00 (head, unspecified); 01 (cranial region, including skull); or 08 (multiple head locations) were examined for inclusion. Five fatalities were found (insect bites, asphyxia, and subarachnoid hemorrhage). None of these fatalities were included. Finally, a series of descriptive analyses were performed using combinations of the injury variables to rule out non-TBIs and validate included TBIs.

Major industry groups were defined using the 2002 North American Industrial Classification System (NAICS) codes.[14] This system classifies industries based on the goods or services they provide. For the present study, industries were identified using both the NAICS major and minor groups.

Statistical Analysis

Occupational TBI fatality rates for 2003–2008 were calculated as the total number of fatalities divided by the estimated number of workers during this period and expressed as the number of fatalities per 100,000 workers per year. Data were analyzed in 2009–2010 using SAS, version 9.2. Gender-, age- and race-specific fatality rates were compared with rate ratios (RRs) and 95% CIs. Fatality rates were calculated and compared between major industry of employer and external cause of injury. Poisson regression was used to assess trends in fatality rates over the 6-year time period.

Results

Occupational Traumatic Brain Injury Fatality Rates

A total of 7294 occupational TBI fatalities were identified between 2003 and 2008, for an average annual fatality rate of 0.8 per 100,000 workers per year (Table 1). Across all event types, TBIs accounted for 22% of all work-related injury fatalities during this time (N=33,641). The exception to this was work-related fall deaths, where almost half (46%, 2130 of 4642) were due to a TBI. The majority of TBIs were intracranial injuries (n=5799, 80%); 17% were firearm-related wounds to the head (n=1245); and 3% were cerebral hemorrhages/concussions (n=250, 3%; data not shown). Men had significantly higher occupational TBI fatality rates compared to women (RR=15.0, 95% CI=13.74, 16.26; Table 1). As age increased, so did occupational TBI fatality rates. Those aged ≥65 years had the highest fatality rate (2.5 per 100,000 per year). The vast majority of TBI fatalities occurred to whites (n=6024, 83%).

External Cause of Injury

Between 2003 and 2008, 31% of all occupational TBI fatalities were motor vehicle–related (n=2240); 29% were due to falls (n=2130); 20% were due to assaults and violent acts

Table 1. Demographic characteristics of occupational TBI fatalities: CFOI, 2003–2008

	Workers[a]	Number of TBI deaths (%)	Rate per 100,000	RR (95% CI)
Gender				
Female	399,204,967	543 (7)	0.1	1.0
Male	458,920,319	6751 (93)	1.5	**15.0 (13.74, 16.26)**
Age (years)				
15–19	37,994,644	215 (3)	0.6	1.0
20–24	82,559,902	573 (8)	0.7	**1.2 (1.04, 1.36)**
25–34	185,146,724	1285 (18)	0.7	**1.2 (1.04, 1.36)**
35–44	206,440,118	1558 (21)	0.8	**1.3 (1.13, 1.47)**
45–54	200,950,096	1662 (23)	0.8	**1.3 (1.13, 1.47)**
55–64	112,925,650	1193 (16)	1.1	**1.8 (1.56, 2.04)**
≥65	32,108,153	808 (11)	2.5	**4.2 (3.64, 4.76)**
Race[b]				
Other[c]	57,821,842	611 (8)	1.1	1.0
White	707,195,764	6024 (83)	0.8	**0.7 (0.64, 0.76)**
Black	93,107,680	634 (9)	0.7	**0.6 (0.55, 0.65)**
Total	858,125,286	7294 (100)	0.8	

Note: Fatality data for the year 2008 are preliminary. Boldface denotes significance at the $\alpha = 0.05$ level.
[a]Worker denominator obtained from the Current Population Survey
[b]Column values do not sum to total because of the exclusion of 25 fatalities with missing race data.
[c]Other races include American Indian, Pacific Islander, and those of multiple races.
CFOI, Census of Fatal Occupational Injury; RR, rate ratio; TBI, traumatic brain injury

(32%). From 2003 to 2006, motor vehicles were the leading cause of occupational TBI death; however in 2007, falls became the leading cause of TBI death (Figure 1). Between 2003 and 2008, occupational TBI fatality rates declined significantly from 0.93 per 100,000 per year to 0.71 per 100,000 ($p<0.0001$). Fatality rates declined for each major cause; however, only motor vehicle–related TBI rates declined significantly (38% decline; 0.29 per 100,000 per year to 0.18; $p=0.0001$).

Table 2 displays the external cause of injury for occupational TBI fatalities by age. For workers aged 15–54 years, motor vehicles accounted for the largest percentage of occupational TBI fatalities. For workers aged ≥55 years, falls were the leading cause of occupational TBI death. Falls accounted for nearly half of all TBI deaths in workers aged ≥65 years ($n=336$, 42%). Although the vast majority of fatal occupational TBIs occurred to men ($n=6751$, 93%), differences ($n=1500$); 18% were due to contact with objects and equipment ($n=1293$); and 2% were due to other events such as explosions and fires ($n=131$; Table 2). Of the 1500 TBIs caused by assault and violent acts, 483 were self-inflicted

Table 2. Number and percentage of occupational TBI fatalities by demographics and cause of injury: CFOI, 2003–2008, *n* (%)

	Contact with objects and equipment	Falls	Motor vehicle–related	Assaults and violent acts	Other events[a]	Total
Age (years)						
15–24	171 (21)	163 (21)	283 (36)	150 (19)	21 (3)	788 (11)
25–34	265 (20)	289 (23)	440 (35)	269 (21)	22 (2)	1285 (18)
35–44	296 (19)	430 (28)	456 (29)	339 (22)	37 (2)	1558 (21)
45–54	279 (17)	492 (30)	513 (31)	348 (21)	30 (2)	1662 (23)
55–64	181 (15)	420 (35)	334 (28)	244 (20)	14 (1)	1193 (16)
≥65	101 (12)	336 (42)	214 (26)	150 (19)	7 (1)	808 (11)
Total	1293 (18)	2130 (29)	2240 (31)	1500 (21)	131 (2)	7294 (100)

Note: Fatality data for the year 2008 are preliminary.
[a]Other events include exposure to harmful substances, fires, and explosions.
CFOI, Census of Fatal Occupational Injury; TBI, traumatic brain injury

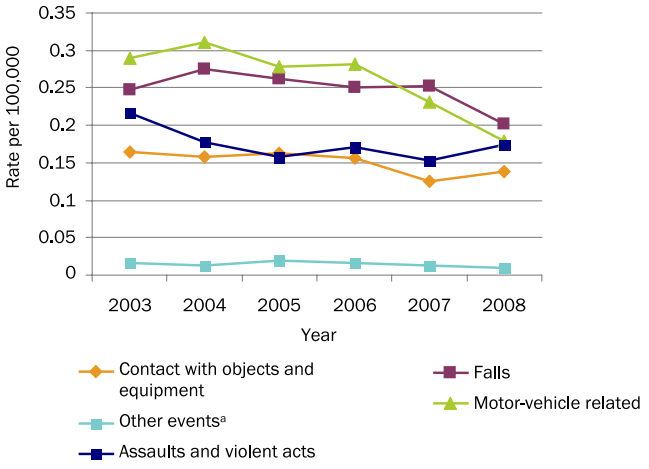

Figure 1. Occupational traumatic brain injury fatality rates
Note: Rates are per 100,000 per year by external cause of injury and year. Data are from the Census of Fatal Occupational Injury, 2003–2008.
[a]Includes exposure to harmful substances, fires, and explosions

in the external cause of these fatalities exist between men and women: The leading cause of occupational TBI death among men was falls and motor vehicles and nearly 50% of occupational TBIs were due to assaults and violent acts among women (n=220, 41%; data not shown).

External Cause of Injury by Industry

Table 3 displays the external cause of injury for occupational TBI fatalities by selected major industry groups. Only those industry groups that had TBI fatality rates higher than the average rate for the period 2003–2008 were included (>0.8 per 100,000 per year). Eight industries accounted for 68% of all occupational TBI fatalities: agriculture, forestry, fishing, and hunting; mining; construction; transportation and warehousing; administration and support services and waste management; public administration; wholesale trade; and arts, entertainment, and recreation. The agriculture, forestry, fishing, and hunting industry had the highest fatality rate among all major industries (5.7 per 100,000 per year; Table 3). The logging sub-industry had the highest occupational TBI fatality rate of all major or minor industries (29.7 per 100,000 per year).

Cause of injury differed by industry. Contact with objects and equipment was the leading cause of occupational TBI death for those in the mining and agriculture industries (n=279, 37% and n=88, 47%, respectively; Table 3). Falls were the leading cause of death for those in the construction industry and accounted for more than half of all TBI fatalities in that industry (n=1038, 57%). In the transportation and warehousing industry, motor-vehicle events were the leading cause of TBI death and accounted for nearly 60% of occupational TBI fatalities (n=489). In the public administration industry, assaults and violent acts were also a leading cause of TBI death, accounting for 44% of all TBI deaths (n=192).

Discussion

This paper provides the first epidemiologic profile of occupational traumatic brain injuries in the U.S. Fatality rates differed substantively between sociodemographic and industry groups. Men, those aged ≥65 years, and those employed in the agriculture, forestry, and fishing industry had higher occupational TBI fatality rates than women, younger workers, and those in other industries. There were also important differences in the cause of injury between sociodemographic and industry groups. This analysis also reveals a change in the cause of occupational TBI death in recent years. From 2003 to 2006, the leading cause of occupational TBI death was motor vehicle–related; however, starting in 2007, falls became the leading cause.

There was an increased risk for occupational TBI mortality among men. An increased risk for occupational injury among men is well documented and extends to both fatal and nonfatal events.[15,16] It has been suggested that the association between gender and workplace injuries is confounded by job title; however, recent work has found that even after adjusting for occupation, men still experience an excess risk for occupational injury.[17] Studies have found that work exposures within occupations are gender-specific and men often perform the more physically demanding job tasks.[18,19] However, because of limitations with CFOI, it was not possible to control for specific work exposures. Also, because of the small number of women in the sample, results could not be stratified by both gender and occupation. The value of gender as a risk factor for occupational injury remains a debatable issue.

There was also an increased risk for occupational TBI mortality among older workers. As age increased, fatality rates increased in a nearly linear fashion until age 65 years, when the fatality rate doubled. Other occupational injury work has demonstrated higher overall fatality rates among older workers.[20–24] Kisner and Pratt found that workers aged >65 years had workplace fatality rates three times that of those aged 16–64 years, after adjusting for hours worked, type of injury, and industry.[20] Other studies have demonstrated elevated occupational fall-related fatality rates among older workers.[23,24] These analyses show that workers aged ≥65 years experienced fatal fall-related TBIs at a rate five times that of workers aged 15–64 years. Factors believed to be associated with this increased risk for fatal TBI among older people include

Table 3. Number and rate of fatal occupational TBI by industry and cause of injury: CFOI, 2003–2008[a]

Industry	Workers (*n*)	Contact with objects and equipment (*n* [%])	Falls (*n* [%])	Motor vehicle–related (*n* [%])	Assaults and violent acts (*n* [%])	Total[b]	Rate per 100,000
Agriculture, forestry, fishing, and hunting	**13,359,706**	**279 (37)**	**99 (13)**	**277 (36)**	**97 (13)**	**761**	**5.7**
Crop/animal and forestry	11,442,294	108 (21)	85 (17)	215 (43)	88 (18)	503	4.4
Logging	654,112	153 (79)	—	29 (15)	—	194	29.7
Fishing, hunting, and trapping	316,890	—	—	6 (3)	—	10	3.2
Support activities for agriculture and forestry	946,410	—	7 (13)	27 (50)	6 (11)	54	5.7
Mining	**3,938,132**	**88 (47)**	**24 (13)**	**49 (26)**	**9 (5)**	**188**	**4.8**
Oil and gas extraction	514,379	10 (45)	—	6 (27)	—	22	4.3
Coal, metal ore, nonmetallic, not specified	1,367,593	23 (49)	—	11 (23)	—	47	3.4
Support activities for mining	2,056,160	55 (46)	18 (15)	32 (27)	—	119	5.8
Construction	**66,814,352**	**313 (17)**	**1038 (57)**	**386 (21)**	**71 (4)**	**1828**	**2.7**
Transportation and warehousing	**37,076,232**	**80 (10)**	**115 (14)**	**489 (59)**	**127 (15)**	**825**	**2.2**
Air, rail, and water transportation	5,467,860	10 (19)	7 (13)	31(60)	—	52	1.0
Truck transportation	11,846,258	45 (9)	76 (15)	340 (69)	28 (6)	496	4.2
Transit services	4,640,723	—	—	24 (22)	81 (75)	108	2.3
Pipeline, scenic, sightseeing and services	4,175,948	17 (20)	11 (13)	46 (54)	7 (8)	85	2.0
Postal and courier	9,019,354	—	—	42 (72)	8 (14)	58	0.6
Warehousing and storage	1,926,089	5 (19)	14 (54)	6 (23)	—	26	1.3
Administrative/support services and waste management	**35,405,346**	**129 (24)**	**153 (29)**	**161 (31)**	**77 (15)**	**525**	**1.5**
Public administration	**39,228,221**	**23 (4)**	**26 (6)**	**188 (44)**	**192 (44)**	**437**	**1.1**
Executive, legislative, public finance	8,096,570	—	—	7 (39)	8 (42)	19	0.2
Justice, public order, and safety activities	16,389,505	13 (3)	12 (4)	126 (44)	137 (47)	293	1.8
Administration	10,670,268	—	—	25 (64)	9 (23)	39	0.4
National security and international affairs	4,071,878	7 (8)	8 (10)	30 (37)	38 (45)	86	2.0
Wholesale trade	**26,699,773**	**52 (21)**	**60 (24)**	**100 (40)**	**32 (13)**	**249**	**0.9**
Arts, entertainment, and recreation	**16,752,473**	**31 (20)**	**38 (25)**	**45 (30)**	**36 (24)**	**152**	**0.9**
Arts and sports	4,629,280	18 (24)	15 (20)	27 (36)	15 (20)	76	1.6
Museums, historical sites, and bowling centers	2,621,952	—	7 (44)	—	5 (31)	16	0.6
Amusement, gambling, and recreation	9,501,241	—	16 (27)	—	16 (27)	60	0.6

Note: Fatality data for the year 2008 are preliminary.
[a]Italicized cells represent either no reported data or data that do not meet Bureau of Labor Statistics reporting criteria.
[b]Rows do not sum to total because "other events" category was omitted from table.
CFOI, Census of Fatal Occupational Injury; TBI, traumatic brain injury

pre-existing comorbidities, cognitive impairment, physical deficiencies, medication use, and sensory deficits.[25,26] Employers should consider addressing these factors in workplace health and safety plans to fully support the work ability of workers as they age.[27,28]

Logging is an extractive industry, with workers exposed to falling trees and limbs, power tools, and heavy machinery in isolated rural areas. The present study found loggers to be at increased risk for fatal work-related TBIs. There is a limited amount of research on logging

injuries; the focus generally has been to document the injury problem and describe the most common injury scenarios.[29–32] This analysis confirmed that despite earlier documentation of the highly hazardous nature of logging activities, there has been a lack of substantial progress toward declining rates.[33,34] In Wrona's analysis of work-related traumatic brain injuries, it was suggested that it would be worthwhile to review prevention efforts in logging and other industries where relative risks are more than 25 and have not changed since 1990.[7] Based on the rate ratio of 37 seen in this current analysis (29.7 per 100,000 workers per year compared to the industry average of 0.8 per 100,000 per year), the authors concur with this recommendation. Increased safety training and certification have been recommended, but thus far, increased mechanization with concurrent reduction of manual cutting tasks appears to be the most promising change to lead to reduced injuries in the logging industry.[35,36]

Over the 6-year period, the U.S. work-related TBI fatality rate declined 23%; this mirrors the decline seen in both overall work-related injury fatality rates and in the overall rate of TBIs (both occupational and non-occupational combined). First, starting in 1992, the rate of work-related fatalities has steadily decreased and since 2002, has held steady at 4.0 per 100,000 people.[15] Second, data on overall U.S. TBI fatality rates also show a decrease (including both occupational and non-occupational events). From 1980 through 1994, the TBI-associated death rate decreased 20%, from 24.7 per 100,000 to 19.8.[37]

These data also demonstrate a change in the leading cause of work-related TBI between 2003 and 2008; starting in 2007, the leading cause shifted from motor vehicle to falls. Between 1980 and 1994, overall TBI fatality rates due to MVCs decreased 38%, from 11.1 per 100,000 per year to 6.9.[37] During this same time, TBI fatality rates due to falls held constant.[37] Another possible explanation for this trend is the increase of older workers in the workforce. Between 1977 and 2007, employment of workers aged ≥65 years increased 101% and has been termed the "graying" of the American workforce.[38] Older workers have been found to be at an increased risk for work-related falls, as well as to be more likely to be injured due to the fall.[39,40] The prevention of falls in the workplace should not discriminate between older and younger workers.[40] Protection standards of the OSHA Regulations (Part 1926 for construction), such as netting, hole covers, guardrails, and personal fall arrest systems will prevent a fall or protect the worker after falling.[41]

Evaluations of occupational safety programs aimed at reducing TBIs are rare. Based on these findings, safety practices aimed at specifically preventing work-related TBIs do not appear to be uniquely applicable to this injury type. For example, increasing mechanization and reducing manual cutting tasks have reduced overall injuries in the logging industry and therefore will also substantially affect work-related TBIs.[35,36] Given that 25% of work-related TBIs came from the construction industry and falls are the leading mechanism of injury in that industry, sound fall prevention programs are essential to the prevention of these events. Like other industries in the U.S., the construction workforce is aging.[42] Although fall prevention is a needed element of occupational safety and health programs in the construction industry, specifically targeting this to older workers would make sense given these results. Other elements that may reduce falls and fall-related TBIs in older construction workers include wellness and fitness classes aimed at increasing flexibility, job modifications to address chronic health problems such as visual or auditory deficits, and occupational therapy targeted to older workers to rehabilitate prior injuries and reduce the chances of re-injury.[42]

There are a number of limitations to these data. Although the CFOI is the most comprehensive surveillance system of occupational fatalities, there was limited information on potential confounding factors such as work conditions, safety practices, use of personal protective equipment, and medical comorbidities. Second, the BLS does not have guidelines for case ascertainment of TBIs using the OIICS. A definition was developed for the present study, based on prior research and BLS expertise. Recent occupational TBI publications have relied on either workers compensation data or trauma registries, both of which utilize the ICD-9-CM.[7–11] Validation steps were performed to ensure the sensitivity and specificity of the case definition. Although the current case ascertainment definition gave a good approximation to these ICD-9-CM codes, there remains a likelihood that brain injuries coded as open wounds, puncture wounds, or avulsions were missed. If true, the numbers of occupational TBIs presented here are underestimates.

Although TBI is an important topic for public health researchers, there has been a lack of attention paid to the investigation of brain injuries occurring in the workplace. Describing the magnitude of the problem, identifying at-risk sociodemographic and occupational subgroups, and documenting trends are vital first steps when developing prevention strategies. Although this research provides a national epidemiologic description of occupational TBI fatalities, it is important to note that this report does not provide data on the scope of nonfatal TBIs occurring in the workplace. Therefore, the impact of occupational TBI is likely far more reaching than the data presented in this manuscript indicate. Future research should enumerate and describe nonfatal occupational TBIs in the U.S. An improved understanding of these

factors should lead to more focused and tailored prevention strategies. With limited resources available for occupational safety and health programs, the identification and targeting of high-risk populations, including older workers, should be a priority for industry.

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