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Fatal Traumatic Brain Injuries in the Construction Industry, 2003–2010

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Background *Research on fatal work-related traumatic brain injuries (TBIs) is limited. This study describes fatal TBIs in the US construction industry.*
Methods *Fatal TBIs were extracted from the Bureau of Labor Statistics Census of Fatal Occupational Injuries.*
Results *From 2003 to 2010, 2,210 fatal TBIs occurred in construction at a rate of 2.6 per 100,000 full-time equivalent (FTE) workers. Workers aged 65 years and older had the highest fatal TBI rates among all workers (7.9 per 100,000 FTE workers). Falls were the most frequent injury event (n = 1,269, 57%). Structural iron and steel workers and roofers had the highest fatal TBI rate per 100,000 FTE workers (13.7 and 11.2, respectively). Fall-related TBIs were the leading cause of death in these occupations.*
Conclusions *A large percentage of TBIs in the construction industry were due to falls. Emphasis on safety interventions is needed to reduce these fall-related TBIs, especially among vulnerable workers.* Am. J. Ind. Med. 59:212–220, 2016. Published 2016. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS: brain injuries; TBI; falls; roofers; occupational; older workers

INTRODUCTION

In the United States, construction is one of the most hazardous among all major industries with a high number of fatalities [BLS, 2014]. In 2013, 828 fatal injuries occurred in the construction industry, with a rate of 9.7 fatalities per 100,000 full-time equivalent (FTE) workers, about three times more than the overall US workplace fatality rate (3.3 per 100,000 FTE workers) [BLS, 2014]. Despite a decline in the overall construction fatality rate from 11.7 per 100,000 FTE workers in 2003 to 9.7 per 100,000 FTE workers in 2013, workers in the industry are still at high risk for death due to work in dynamic conditions such as working at heights, excavations, falling objects, and working with power tools and equipment [BLS, 2003a; CDC, 2011; CPWR, 2013]. Studies have found that falls and struck-by incidents were the most common injury mechanisms in the construction industry, and workers in this industry are at high risk for fatal head injuries due to these events [Janicak, 1998; Tiesman et al., 2011; Konda et al., 2014; Chang et al., 2015]. Despite the high risk of brain injury, only a few studies have described work-related traumatic brain injuries (TBIs) in the US construction industry [Janicak, 1998; Wrona, 2006; Tiesman et al., 2011; Kica and Rosenman, 2014; Konda et al., 2014]. Recent national-level analyses on TBIs found that the greatest number of both fatal and nonfatal TBIs occurred in the construction industry. In regard to rates, the construction industry ranked third in TBI fatality rates from 2003 to 2008 and fourth in nonfatal TBI rates from 1998 to 2007 among all major industries [Tiesman et al., 2011; Konda et al., 2014]. However, no studies have described specific characteristics associated with fatal TBIs in the US construction industry. Work-related fatal TBIs can be prevented and a complete understanding of factors leading to TBIs is essential to identify preventive measures aimed at these injuries. Therefore, the objective of this study was to examine the demographic characteristics of fatally injured workers,

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assess trend in rates over time, identify leading events, and identify specific occupations at the highest risk for work-related fatal TBIs in the US construction industry.

METHODS

Data Sources

Data on fatal TBIs that occurred from 2003 to 2010 were obtained from the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI).[1] During these years, CFOI used the Occupational Injury and Illness Classification System (OIICS), version 1.01 to code injury case characteristics [BLS, 2007]. In 2011, CFOI implemented version 2.01 of the OIICS and considered this code change to be a break in series. Thus, data analyses were restricted to years prior to 2011. BLS defines work-related fatalities as those occurring to non-institutionalized persons working at the time of the incident, on or off the employer's premises. CFOI is a federal-state cooperative program that collects fatal work-related injury data from all 50 states and the District of Columbia. Fatal injuries were compiled by cross-referencing multiple source records, such as death certificates, workers' compensation reports, federal and state agency administrative reports, Occupational Safety and Health Administration (OSHA) investigation reports, medical examiner reports, news media, and police reports. A work relationship criterion is substantiated with two or more independent source documents, or a source document and a follow-up questionnaire [BLS, 2003b]. In this study, workers in the construction industry were selected from CFOI using the 2002 (2003–2008) and 2007 (beginning 2009) North American Industry Classification System code for construction [OMB, 2002]. From 2003 to 2010, CFOI classified occupations using the 2000 Standard Occupational Classification system [OMB, 2000].

The denominator data to calculate fatality rates were obtained from the BLS's Current Population Survey (CPS).[2] It is a monthly survey that provides employment-related information of approximately 60,000 civilian, non-institutionalized residents aged 16 years and older. Because the CPS excludes military personnel, military deaths from CFOI were excluded from this study [BLS, 2012a]. The denominator data for the construction industry were selected by the 2002 (2003–2008) and 2007 (beginning 2009) Bureau of Census (BOC) industry code for construction [U.S. Census Bureau, 2002]. From 2003 to 2010, the CPS defined occupations using the 2002 BOC occupation codes [U.S. Census Bureau, 2002].

The CPS data do not collect denominator data on establishment size. Thus, an additional data source, the County Business Patterns (CBP) was used to calculate fatal TBI rate by establishment size. Establishment size categories in the CBP were matched with establishment size categories in CFOI to allow calculation of fatal TBI rates by establishment size. The CBP is an annual establishment survey conducted by the U.S Census Bureau that provides industry data by establishment size and employment, but is limited to businesses with wage and salary workers [U.S. Census Bureau, 2012]. TBI fatalities among self-employed construction workers were excluded from the CFOI data to match with the denominator data of the CBP. Consequently, the rates by establishment size is limited to wage and salary workers. Also, 28% of the TBI fatality records in CFOI were missing data on establishment size and could not be used in the calculation of rates by specific establishment sizes.

TBI case identification

CFOI uses the OIICS to code the nature of injury, body part affected, source and secondary source of injury, and injury event of fatal injuries [BLS, 1992]. No guidelines exist for TBI case ascertainment using CFOI. Thus, the authors used the general TBI case definition based on a previous study [Tiesman et al., 2011]. First, the following OIICS codes for nature of injury were used to obtain TBIs: 060 (intracranial injuries, unspecified), 061 (cerebral hemorrhages), 062 (concussions), 068 (multiple intracranial injuries), and 069 (intracranial injuries, not elsewhere classified). Second, a combination of the codes for body part affected and nature of injury codes were used to obtain additional TBIs due to all firearm-related incidents. 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 the injury code equaled 036 (gunshot wounds).

After cases were identified, a systematic approach was used to validate these cases based on the TBI definition. The TBI case definition excludes instances of intracranial hemorrhage without external trauma. Thus, all TBIs were validated using the combination of the nature of injury and injury event to identify cases that resulted due to a physiologic hemorrhagic stroke without a traumatic injury to the head. After review, it was determined that all TBIs were caused by traumatic injury events (such as contact with objects and equipment, falls, transportation incidents, fires and explosions, and assaults and violent acts) and no cases were deleted.

Statistical Analysis

TBI fatality counts and percentages were calculated for demographic characteristics, establishment size, injury event, and occupation. TBI rates per 100,000 FTE workers

[1] Additional information can be found at: http://www.bls.gov/iif/oshcfoi1.htm

[2] Additional information can be found at: http://www.census.gov/cps/

were calculated as the number of workers with fatal TBIs divided by the estimated FTE workers using the employment data from the CPS. One FTE worker represents 2,000 hr worked in a year. The rates presented are for civilian workers. For establishment sizes, rates per 100,000 wage and salary workers were calculated as the number of wage and salary workers with fatal TBIs divided by the number of employees obtained from the CBP. Rate ratios (RR) with 95% confidence intervals (CI) were calculated to compare rates among demographic characteristics and establishment sizes. Trends in fatality rates over the 8-year time period were assessed using Poisson regression. The data were tested for dispersion and results indicated the dispersion parameters were slightly less than 1. Thus, reported CIs are conservative. All analyses were conducted using SAS version 9.3. The BLS CFOI data are generated from a routine, ongoing surveillance effort and do not have personal identifiers. Thus, Institutional Review Board approval was not required. This research was conducted with restricted access to BLS data. The views expressed here do not necessarily reflect the views of the BLS.

RESULTS

From 2003 to 2010, 2,210 construction workers died because of a TBI at a rate of 2.6 per 100,000 FTE workers (Table I). These deaths represented 25% of all construction fatalities (n = 8,913) and 24% of all occupational TBI fatalities (n = 9,068) during the same period (data not shown). The rate of fatal TBIs in construction decreased annually by 6.2% (95%CI: 5.0–7.4%) from 2003 to 2010 ($P < 0.0001$; Fig. 1). Similarly, the overall fatality rate in construction decreased annually by 3.5% (95%CI: 2.6–4.4%) during the same period ($P < 0.0001$). Also, the overall occupational TBI fatality rate decreased by an average of 5.2% (95%CI: 4.3–6.2%) per year from 2003 to 2010 ($P < 0.0001$; data not shown). Male workers had significantly higher TBI fatality rates compared with female workers (Table I). Older workers (65 years and older) had significantly higher TBI fatality rates compared with workers aged 25–34 years. Hispanic and black, non-Hispanic workers had a significantly higher risk for a TBI fatality than white, non-Hispanic workers. The TBI fatality rate for foreign-born[3] workers was significantly higher than that of native-born[4] workers. Also, the TBI fatality rate for foreign-born Hispanic workers was significantly higher than that of native-born Hispanic workers. Among the TBI deaths that occurred among Hispanic construction workers, 80% (546 of 681) were foreign born (Table I).

TABLE I. Number, Rate per 100,000 FTE Workers, and Rate Ratio of Fatal TBIs in the Construction Industry by Demographic Characteristics—US, 2003–2010

Characteristics	n (%)	Rate	Rate ratio (CI)
Sex			
Female	28 (1)	0.4	1
Male	2,182 (99)	2.8	**7.1 (6.8–7.4)**
Age group (in years)			
16–19	75 (3)	4.6	**2.2 (1.7–2.7)**
20–24	192 (9)	2.4	1.2 (0.9–1.3)
25–34	460 (21)	2.1	**1**
35–44	514 (23)	2.3	1.1 (0.9–1.2)
45–54	538 (24)	2.7	**1.3 (1.2–1.4)**
55–64	296 (13)	3.4	**1.6 (1.4–1.8)**
65 and older	135 (6)	7.9	**3.8 (3.1–4.4)**
Race/ethnicity			
White, non-Hispanic	1,343 (61)	2.3	1
Black, non-Hispanic	129 (6)	3.0	**1.3 (1.1–1.6)**
Asian, non-Hispanic	29 (1)	2.6	1.1 (0.7–1.5)
Hispanic	681 (31)	3.5	**1.5 (1.4–1.7)**
Other[a]	20 (1)	1.5	**0.6 (0.4–0.9)**
Unknown	8 (<1)	NA	NA
Foreign-born status			
Native born	1,560 (71)	2.4	1
Foreign born	650 (29)	3.6	**1.5 (1.4–1.6)**
Ethnicity/foreign-born status[b]			
Hispanic			
Native born	135 (6)	2.7	1
Foreign born	546 (25)	3.8	**1.4 (1.2–1.7)**
Non-Hispanic			
Native born	1,418 (64)	2.3	1
Foreign born	104 (5)	2.6	1.1 (0.9–1.3)
Total	2,210 (100)	2.6	NA

Fatal counts and rates were generated by the authors with restricted access to CFOI microdata.
Bold face type denotes statistical significance of rate ratios.
FTE, full-time equivalent; CI, confidence interval; NA, not applicable.
[a]Include American Indian, Alaskan natives, Pacific Islander, and multiple races.
[b]Fatalities do not sum to total because of omission of unknown ethnicity cases.

Approximately, 43% of all TBIs occurred in establishments with fewer than 20 employees (Table II). Establishments with fewer than 20 employees and 20–49 employees had significantly higher TBI rates than establishments with 100 or more employees.

During the 8-year period, the majority of fatal TBIs were due to falls, followed by transportation incidents (Table III). Similarly, construction workers had the highest TBI fatality rate due to falls. These fall-related TBIs accounted for 42% of all construction fall-related fatalities (n = 2,982; data not

[3] The foreign born are persons who reside in the United States but who were born outside the country or one of its outlying areas to parents who were not US citizens.
[4] The native born are persons who were born in the United States or one of US outlying areas or born abroad to born abroad to US citizen-parents.

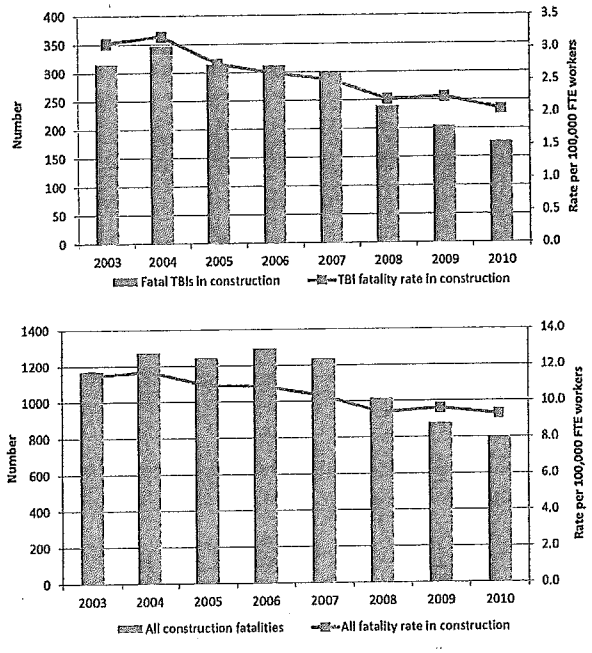

FIGURE 1. Number and rate of all fatalities and fatal TBIs in the construction industry by year—US, 2003–2010.

shown). As age increased, the percentage of fatalities due to fall-related TBIs also increased. Fall-related TBIs accounted for two-thirds of all fatal TBIs among construction workers aged 65 years or older. Also, workers aged 65 years or older had the highest fatal TBI fatality rates in the construction industry, including the highest fall-related and transportation-related TBI rates.

Occupations with TBI fatality rates greater than the overall construction industry TBI fatality rate are included in Table IV (i.e., >2.6 per 100,000 FTE workers per year). These 10 occupations accounted for more than half of all fatal TBIs in the construction industry. Structural iron and steel workers had the highest TBI fatality rate, followed by roofers. However, the highest number of fatal TBIs occurred among construction laborers. Injury event varied among occupations. Fatalities due to falls were the leading cause of TBI death among many occupations, especially among roofers. Other occupations (not listed in the table) with high percentage of fall-related TBI fatalities were painters (90%), drywall and ceiling installers (88%), carpenters (78%), electricians (69%), and construction managers (51%). TBI fatalities due to transportation incidents were the leading cause among paving surfacing and tamping equipment operators, light and heavy truck drivers, and highway maintenance workers.

Falls to a lower level accounted for the majority of fall-related TBIs (Table V). Of these, approximately, three-fourths of TBI fatalities were falls from a roof, scaffold/staging, or ladders. A large proportion of TBIs (75%) occurred during day time from 8:00 to 4:59 pm, especially between 10:00 and 10:59 am (n = 235, 11%). The highest TBI fatality rate per 100,000 FTE workers was observed in August for those working in the Northeast (3.7), in October for workers in the Midwest (3.0) and West (2.9) regions, and in March, for workers in the South region (3.6; data not shown).

DISCUSSION

Over the 8-year study period, both the number and rate of fatal work-related TBIs decreased in the construction industry similar to the decrease in overall fatal work-related injuries in the construction industry [BLS, 2003a, 2014]. Several reasons may explain this considerable decrease. First, this may mirror decreases seen in overall work-related fatality rates, the overall work-related fatal TBI rate, and overall fatal TBI rates (including work-related and non-work-related events) during the same time period. The overall work-related fatality rate decreased 10% from 4.0 per 100,000 per FTE workers in 2003 to 3.6 per 100,000 FTE

TABLE II. Number and Rate of Fatal TBIs per 100,000 Employees in the Construction Industry by Establishment Size—US, 2003–2010

Establishment size (no of employees)[a]	n (%)	Rate[b]	Rate ratio (CI)
1–19	762 (43)	3.7	**2.6 (2.2–2.9)**
20–49	197 (11)	1.8	**1.3 (1.1–1.5)**
50–99	113 (6)	1.6	1.1 (0.9–1.3)
100 and more	210 (12)	1.4	1
Unknown[c]	507 (28)	NA	NA
Total	1,789 (100)	3.4	NA

Fatal counts and rates were generated by the authors with restricted access to CFOI microdata.
Bold face type denotes statistical significance of rate ratios.
CI, confidence interval; NA, not applicable.
[a]Rates by establishment size is based on fatalities among wage and salary workers only. Fatal TBIs among self-employed workers and TBI fatalities not reported by type of employment in construction (n = 421) were excluded to match with the County Business Patterns (CBP) denominator data.
[b]Rates per 100,000 employees were calculated using labor estimates from the CBP.
[c]Establishment size is missing for TBI fatality records in CFOI.

TABLE III. Number and Rate of Fatal TBIs per 100,000 FTE Workers in the Construction Industry by Age and Event Type—US, 2003–2010

	Contact with objects and equipment		Falls		Transportation incidents		Other[a]	
Age group (in years)	n (%)	Rate	n (%)	Rate	n (%)	Rate	n (%)	Rate
16–19	—	0.9	38 (51)	2.3	20 (27)	1.2	—	0.1
20–24	46 (24)	0.6	99 (52)	1.3	39 (20)	0.5	8 (4)	0.1
25–34	95 (21)	0.4	247 (54)	1.1	107 (23)	0.5	11 (2)	0.1
35–44	92 (18)	0.4	299 (58)	1.3	101 (20)	0.4	22 (4)	0.1
45–54	62 (12)	0.3	315 (59)	1.6	114 (21)	0.6	47 (9)	0.2
55–64	40 (14)	0.5	183 (62)	2.1	57 (19)	0.7	16 (5)	0.2
65 and older	—	0.8	88 (65)	5.2	25 (19)	1.5	—	0.5
Total	363 (16)	0.4	1269 (57)	1.5	463 (21)	0.6	115 (5)	0.1

Fatal counts and rates were generated by the authors with restricted access to CFOI microdata.
Dashed cells represent either no data or data do not meet minimum reporting criteria.
FTE, full-time equivalent.
[a]Other includes fires and explosions, assaults and violent acts, and unknown events.

workers in 2010 [BLS, 2003a, 2011] and the overall work-related fatal TBI rates significantly decreased annually. Also, the overall fatal work and non-work TBI death rates decreased 6% from 18.2 per 100,000 to 17.1 between 2003 and 2010 [NCIPC, 2014]. Second, another hypothesized reason for the decrease in fatal TBI rates is improvements made in the triage and transport of TBI patients [Fakhry et al., 2004; Hartl et al., 2006; Tiesman et al., 2007; Coronado et al., 2012]. Third, the decrease in construction employment and a substantive drop in construction spending during the economic downturn from 2007 likely contributed to the drop in the number of fatal TBIs in the US construction industry [U.S. Census Bureau, 2002, 2010; Dong et al., 2010, 2013; CDC, 2011; BLS, 2012b]. The decrease in employment from 2003 to 2010 was not consistent across the construction industry. Some of the largest drops in employment were seen among workers working more than 40 hr per week, whereas the number of workers working less than 30 hr per week increased [BLS, 2012a]. Long hours or overtime work have been shown to increase the risk for work injuries [Dembe et al., 2005]. This suggests that the decrease in the number of workers working long hours may have been a factor in the decline of fatal TBI rates. Finally, the downward trend of rate of fatal TBIs in the construction industry suggests that the industry may have reduced the burden of workplace injury through various safety measures such as those recommended by OSHA in Worker Safety Series Pocket Guide for construction safety in 2005 [OSHA, 2005].

Construction is a male-dominated industry with males representing 92% of the workforce during the study period [BLS, 2012a]. In our study, male workers had a higher risk for occupational TBI mortality compared to female workers. This may be attributed to different job tasks between male and female workers, with the job tasks of male workers typically exposing the worker to physical and hazardous work conditions [Tiesman et al., 2011]. In our study, because women accounted for such a small portion of fatal TBIs, gender-specific analysis could not be performed. Further research is needed to better understand gender-based exposure and risk differences.

In 2013, Hispanic workers represented about 15% of FTEs in all industries and just over half were foreign born [BLS, 2013]. However, in the construction industry, they represented 25% of all FTEs and almost three-fourths were foreign born [BLS, 2013]. In our study, we found high fatal TBI rates among Hispanic and foreign-born workers, separately. When fatal TBI rates among Hispanics were analyzed by nativity, the foreign-born rate was significantly higher than the native-born rate. Dong et al. [2009] also noted high rates of fatal falls among Hispanic construction workers, but in multivariate modeling, ethnicity fell out, and nativity (foreign-born status) was the significant predictor of death. Likewise, Byler [2013] found that the fatal injury rate for native-born Hispanic workers was lower than that for all workers, but the fatality rate for foreign-born Hispanic workers was significantly higher. Orrenius and Zavodny [2009] reported that immigrants tend to work in riskier industries and occupations as compared to native workers. Also, foreign-born Hispanic workers are more likely than all native-born workers to have barriers to occupational safety such as limited proficiency in the English language [NCOSH Project, 2000; Capps et al., 2003] and lack of knowledge of worker safety laws and rights [NCOSH Project, 2000]. The AFL-CIO [2005] compiled a report suggesting multiple actions that would improve immigrant worker health and safety, including provision of language appropriate training, and requiring targeted enforcement programs to address immigrant workers at high injury or illness risk.

TABLE IV. Number and Rate of Fatal TBIs per 100,000 FTE Workers in the Construction Industry by Select Occupations—US, 2003–2010

Occupation	Contact with objects and equipment n (%)[a]	Falls n (%)	Transportation incidents n (%)	Total n (%)[b]	Rate
Structural iron and steel workers	10 (18)	39 (68)	—	57 (3)	13.7
Roofers	—	176 (93)	8 (4)	190 (9)	11.2
Paving surfacing and tamping equipment operators	—	—	12 (86)	14 (<1)	7.9
Electrical power-line installers and repairers	—	11 (73)	—	15 (<1)	7.6
Construction laborers	143 (26)	306 (55)	96 (17)	559 (25)	5.5
Light/heavy truck drivers	—	8 (11)	58 (79)	73 (3)	5.0
Welding, soldering, and brazing workers	8 (24)	17 (52)	—	33 (1)	4.6
Highway maintenance workers	—	—	22 (85)	26 (1)	3.7
Cement masons and concrete finishers	—	7 (35)	8 (40)	20 (1)	2.8
First-line supervisors/managers of construction trades and extraction workers	27 (15)	92 (51)	39 (22)	179 (8)	2.8
All other occupations	155 (15)	612 (59)	209 (20)	1,044 (47)	1.7
Total	363 (16)	1,269 (57)	463 (21)	2,210 (100)	2.6

Fatal counts and rates were generated by the authors with restricted access to CFOI microdata.
Dashed cells represent either no data or data do not meet minimum reporting criteria.
FTE, full-time equivalent.
[a]Number in parenthesis denotes row percentage. Row numbers do not sum to 100% because of dashed cells with no data and omission of "other event" column from the table.
[b]Number in parenthesis denotes column percentage.

Employers with fewer than 20 workers accounted for 41% of the wage-and-salary construction workforce in 2010 [U.S. Census Bureau, 2012]. Our study found that fatal TBI rates in construction were inversely proportionate to the employer size, with small employers having significantly higher rates than large employers. A similar pattern was noted among all fatal construction injuries with 56% of fatalities occurring among employers with fewer than 20 employees [CPWR, 2013]. Smaller construction companies are less likely to provide comprehensive occupational health and safety programs due to restricted resources and limited injury reporting requirements. To help address this, OSHA provides resources and information specifically targeted to small businesses [OSHA, 2015]. In addition to occupational health and safety constraints due to size, small construction businesses are also more likely to need to tailor occupational safety and health efforts to include Hispanic workers as smaller construction firms employing 1–10 workers, employ 46% of all Hispanic workers as compared to 36% of all non-Hispanic workers [Dong et al., 2011].

Similar to previous studies, our study found that falls accounted for more TBI-related construction fatalities than any other injury event [Wrona, 2006; Colantonio et al., 2009; Tiesman et al., 2011; Liu et al., 2013]. In particular, older workers had the highest fall-related TBI rate [Tiesman et al, 2011; Konda et al., 2014]. Older workers may be at risk for fall-related TBI due to pre-existing health conditions, cognitive impairment, or impaired mobility due to aging, medication, and sensory deficits [Tinetti et al., 1995; Moyer, 2012]. Older workers not only are at a higher risk for fatal injuries but also experience more severe injuries, require longer time away from work to recover, and have higher medical costs [Schwatka et al., 2012]. Workers aged 65 years and older are projected to increase from 4.4% in 2010 to 7.4% in 2020 for the overall workforce [CPWR, 2013]. As workers remain on the job longer, planning for their occupational health and safety is critical, especially in physically demanding jobs like construction. Therefore, employers should assess and modify job duties to accommodate potential changes in the physical and cognitive capabilities of aging workers, such as revising their schedules and tasks when possible [Dong et al., 2012]. Workplace programs that promote healthy life styles and physical exercise, particularly, activities that improve strength, balance, and coordination also help reduce injury risk [CDC, 2013]. Also, workers should monitor some medicines or combinations of medicines they are taking that may cause side effects, such as dizziness or drowsiness, as these may increase the risk of falling [Colantonio et al., 2009; CDC, 2013].

Many occupations, especially roofers, are at risk for falls from heights. We found that nearly three-fourths of TBI fatalities occurred due to falling from roofs, scaffold/staging, or ladders. To prevent falls from roofs, ladders, and scaffolds, the National Institute for Occupational Safety and Health (NIOSH), OSHA, and the CPWR—Center for Construction Research and Training started a nationwide construction falls-prevention campaign that encourages employers to reduce or eliminate the need of extended working at elevation, to provide appropriate and safe equipment while working at elevation (such as aerial lifts, supported scaffolds,

TABLE V. Number and Percent of Fall-Related Fatal TBIs in the Construction Industry—US, 2003–2010

Falls	n (%)
Fall to lower level	1,221 (96)
Fall to lower level, unspecified	28 (2)
Fall to down stairs or steps	14 (1)
Fall from floor, dock, or ground level	73 (6)
Fall from ladder	301 (24)
Fall from roof	388 (31)
Fall from scaffold, staging	212 (17)
Fall from building girders or other structural steel	50 (4)
Fall from nonmoving vehicle	66 (5)
Fall to lower level, not elsewhere classified (n.e.c)	89 (7)
Fall on same level	25 (2)
Fall to floor, walkway, or other surface	19 (2)
All other[a]	6
Other[b]	23 (2)
Total	1,269 (100)

[a]Includes unspecified fall on same level, fall onto or against objects, and fall on same level, n.e.c.
[b]Includes unspecified fall, jump to lower level, and fall, n.e.c.

harnesses, mast climbing platforms, and ladders), and to train workers in hazard recognition and the use of specific equipment to complete the job safely [CDC, 2012]. Also, to improve extension ladder safety, NIOSH released a smartphone application, which provides graphic-oriented and easy-to-use ladder safety tools and information for safe ladder positioning [NIOSH, 2014].

Although helmets in construction work are intended to protect workers from falling objects, penetration hazards, and electrical shock, they do not always provide sufficient protection against falls and other events that may lead to a TBI as helmets are often strapless and may come off during a fall. To improve the safety and reduce the severity of fall-related TBIs, there is a need for improvement in helmet design. Because the safety helmet is the only source of protection against a fall-related TBI, specific focus and continued research related to the effectiveness of helmets in the reduction of TBI severity is needed so that deaths may be prevented from these injuries [Colantonio et al., 2009; Long et al., 2013].

To our knowledge, this is the first study to focus on fatal TBIs in the US construction industry. Although our study provides a description of TBIs in the US construction industry using data from a well-established national surveillance program, it has limitations. First, the BLS CFOI does not have guidelines for case ascertainment of fatal TBIs using OIICS. However, the authors used the TBI definition based on a prior research study [Tiesman et al., 2011]. Because the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes are not available in CFOI, any other potential fatal TBI cases will be missed. Moreover, Sears et al. [2013] reported that OIICS-based TBI case identification captures only a portion of fatal occupational TBIs because of lack of sufficient information surrounding the circumstance of the deaths or presence of severe multiple injuries which can obscure a TBI. Thus, the number of fatal TBIs presented here are underestimates. Second, the fatal TBI rate by employer size was limited to payroll employees only to match the available denominator data. However, as self-employed workers accounted for approximately a quarter of the construction workforce from 2003 to 2010 [BLS, 2012a], this exclusion limitation likely impacted fatal TBI rates by employer size. Also, 28% of the TBI fatality records in CFOI had missing data on establishment size. Thus, we are unable to determine the effect of fatalities with unknown establishment size on fatal TBI rates by establishment size.

Workers in the construction industry have one of the highest fatality rates of all industries, and a quarter of all construction industry deaths are caused by TBIs. Worker groups identified to be at highest risk for fatal TBI within the construction industry included older workers, foreign-born Hispanics, and workers employed in smaller establishments. Falls were the most common injury event and were particularly prevalent among occupations such as roofers, painters, construction laborers, and dry wall and ceiling installers. Thus, despite declining fatal TBI rates from 2003 to 2010, it is imperative that prevention efforts addressing work-related TBIs continue to be implemented and improved. This study provides findings that can help target such efforts. Future research should enumerate and describe nonfatal occupational TBIs in the US construction industry so that TBI prevention efforts can focus on providing safety training tailored toward the worker groups at highest risk as well as the use and further development of safety equipment and tools specific to work tasks. Such efforts can benefit workers and employers by reducing both fatal and nonfatal TBIs in the construction industry.

AUTHORS' CONTRIBUTIONS

Srinivas Konda was involved in all aspects of the study including, conceptualizing, designing the analysis, interpreting results, and writing the article. Hope Tiesman and Audrey Reichard were involved in writing and editing section of the article. The authors have participated in reviewing and approved the final version.

AUTHORS' DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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Steven Markowitz declares that he has no competing or conflicts of interest in the review and publication decision regarding this article.

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