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Risks of a Lifetime in Construction Part I: Traumatic Injuries

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Background *Estimates of occupational risk are typically computed on an annual basis. In contrast, this article provides estimates of lifetime risks for fatal and nonfatal injuries among construction workers. A companion paper presents lifetime risks for occupational illnesses.*

Methods *Using 2003–2007 data from three large data sources, lifetime risk was computed based on the number of fatal and nonfatal injuries per 100 FTEs for a working lifespan of 45 years.*

Results *For a working life in construction, the risk of fatal injuries were approximately one death per 200 FTE, and the leading causes were falls and transportation incidents. For nonfatal injuries resulting in days away from work, the adjusted lifetime risk was approximately 78 per 100 FTEs, and the leading causes were contact with objects/equipment, overexertion, and falls to a lower level.*

Conclusions *Lifetime risk estimates help inform both workers and policymakers. Despite improvements over the past decades, risks in construction remain high.* Am. J. Ind. Med. 57:973–983, 2014. *© 2014 Wiley Periodicals, Inc.*

KEY WORDS: lifetime risk; construction; fatalities; nonfatal injuries; working lifespan; falls; contact with objects/equipment; overexertion

INTRODUCTION

Hazards of working life are usually described as relative risks based on annual injury rates. While such cross-sectional studies are useful, they tend to understate risks since they only reflect certain time points [Robinson, 1986]. Longitudinal cohort studies can improve on these deficiencies [Schubauer-Berigan et al., 2009; Neitzel et al., 2011], but those studies are difficult to maintain due to reasons such as investigators losing interest/funding or participants leaving the cohort. Consequently, there have been very few longitudinal studies of occupational risks [Arndt et al., 2005]. Additionally, most studies present risks as relative rather than absolute risks, which makes it difficult for the general population to understand from a public health perspective.

It is well recognized that the construction industry is one of the largest and most dangerous industries in the U.S. [Ringen et al., 1995; National Research Council, 2009; CPWR, 2013]. Despite injury reductions due to continuous intervention efforts, the construction industry still reports more fatalities than any other industry (U.S. Bureau of Labor Statistics (BLS), 2013a). Moreover, deaths and injuries from falls represent a major and persistent problem in construction (BLS, 2013a). The nonfatal injury rate in construction also has been higher than in other goods-producing industries in most years. The rate of cases with days away from work in construction was about 40% higher than that of all private industries (BLS, 2013b). Therefore, construction is regarded as one of five "high risk professions" given special consideration in Paragraph 9001 of the 2010 Patient Protection and Affordable Care Act (Pub.L. 111–148; 124 Stat. 119, codified). While the Act does not define what "high risk" is, presumably it is based on the experience of the last

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generation of workers in the specified industries. Due to the high risks construction workers have experienced and will continue to face, exploring the risks during a worker's lifespan could further illuminate the high risks in this industry in order to set priorities for developing interventions.

Construction is also a dynamic and complex industry sector that consists of mainly small employers. In 2009, there were more than 700,000 establishments in the industry; about 83% employed less than 10 workers, and 99% employed less than 100 workers [U.S. Census Bureau, 2010]. Changes in the economy and housing market in the U.S. have made construction safety and health more complicated and unpredictable than ever before. In 2006, the number of occupational fatalities in construction peaked at almost 1,300, but dropped to about 800 by 2010 (Appendix I). In part, the decline reflected the impact of the economic downturn (BLS, 2011). The construction workforce significantly expanded from 7.0 million in 1992 to 11.8 million in 2007, and then fell to 9.1 million by 2010 due to the recession.

The most dramatic change in the construction industry has been the growth of Hispanic workers since the early 1990s. The number of Hispanic construction workers increased from about 700,000 in 1992 to nearly 3 million in 2007 [CPWR, 2013]. The subsequent economic downturn seriously affected Hispanic employment in construction. During the recession, about one of three Hispanic construction workers lost employment [CPWR, 2013]. With the economic recovery, Hispanic reemployment and new entry in the workforce are expected to grow [Pew Hispanic Center, 2012]. Hispanic construction workers tend to be inexperienced young immigrants who do not speak English very well, are less-educated, take low-skilled jobs, and are more likely to suffer from work-related injuries than their non-Hispanic counterparts [Brunette, 2004; Dong and Platner, 2004; CPWR, 2013; CDC, 2008; Dong et al., 2009, 2010a,b, 2011, 2013]. Although the ethnic disparities in safety and health risks among construction workers have been well-documented, the magnitude of risks that Hispanic construction workers face over a working life has never been examined.

The construction industry, like many other industries, is aging [CPWR, 2013]. The workforce has steadily increased in average age, but new and younger workers will enter the industry as the baby boomer generation transitions into retirement and overall employment increases in the next decade (BLS, 2013c). Introducing young workers to the risks of their work in a more meaningful way should help them better understand the risks they face and engage them in finding solutions to make the industry safer, and perhaps accelerate the significant improvements that have been achieved in recent decades.

Although it has been shown in other areas of public health that presenting risks over a lifetime can have a significant effect on shaping public policy priorities, including breast cancer [Phillips et al., 1999], hypertension [Vasan et al., 2002], dementia [Seshadri et al., 1997], cardiovascular disease [Wilkins et al., 2012], and diabetes [Narayan et al., 2011], few attempts have been made to present risks in this manner in occupational safety and health. There is only one published report on lifetime risks in the construction industry (Fosbroke et al., 1997), and it was limited to incomplete data on occupational fatalities since it was performed before the Census of Fatal Occupational Injuries (CFOI) data were available.

This study presents a significantly broader perspective on risks, by stratifying lifetime risk in construction according to occupation, leading cause, and ethnicity for both fatal and nonfatal occupational injuries. The findings of this study will provide new risk assessments that should inform the formation of construction safety and health policies, and provide a frame of reference for job seekers who intend to work in the construction industry.

MATERIALS AND METHODS

To estimate lifetime risk in the construction industry, this study focused on fatal and nonfatal traumatic injuries by analyzing three large nationally representative datasets.

Census of Fatal Occupational Injuries (CFOI; http://www.bls.gov/iif/oshcfoi1.htm). The CFOI is a federal-state cooperative program that has been implemented in all 50 states and the District of Columbia since 1992. Data on deaths resulting from injuries at work are compiled from government sources, such as death certificates, workers' compensation reports, Occupational Safety and Health Administration (OSHA) reports, and medical examiner reports. Both the death and the work-relatedness of the death must be corroborated by at least two data sources or a single data source and a follow-up questionnaire. States are allowed to revise the reports within 1 year. Deaths occurring during a commute to or from work are not considered work-related, but vehicle-related deaths during the course of work are included. The calculations of fatality rates include the public and private construction sectors and self-employed workers, unless otherwise noted. Thus, the numbers presented here may differ from those in the U.S. Bureau of Labor Statistics' (BLS) publications that include only deaths in the private sector.

Survey of Occupational Injuries and Illnesses (SOII; http://www.bls.gov/respondents/iif). The SOII provides the numbers of nonfatal injuries and illnesses. The SOII is a federal-state program in which employer reports are collected annually from private industry establishments and processed by state agencies cooperating with the BLS. The sample of workplaces selected by the BLS for participation in the SOII consists of approximately 230,000 private industry establishments each year. Self-employed workers, farms with fewer

than 11 employees, private households, and federal government agencies are not covered in the SOII data collection.

Current Population Survey (CPS; http://www.census.gov/cps). The CPS is a monthly survey of households conducted by the U.S. Census Bureau for the BLS. Estimates from the CPS are based on a scientific sample of about 60,000 housing units per survey. Each month, interviewers contact the sampled units to obtain basic demographic information about everyone living at the address, including age, gender, race, and Hispanic origin. For those aged 16 years or older, the survey collects detailed information on employment, including occupation, industry, and number of hours worked.

When calculating rates, the number of injuries from the CFOI and SOII were used as numerators, while the number of construction workers and hours worked from the CPS were used as denominators. Nonfatal injury risk estimates only cover injuries resulting in days away from work (DAFW) among wage-and-salary construction workers in the private sector. The SOII only provides detailed information on DAFW cases, and such injuries are major concerns for workplace interventions. The SOII data on public sector workers are available after 2008, and thus are not included in the study. To match the data from the SOII, self-employed workers and workers in the public sector were excluded from the CPS estimates. While self-employed workers constituted almost 30% of the construction workforce, less than 5% of construction workers were employed in the public sector.

The following formula developed by OSHA has been used to calculate working lifetime risks (WLTR) for U.S. industries by several researchers [Fosbroke et al., 1997; Drudi, 1998; Sygnatur, 1998]. Lifetime risk was assumed to be a 45-year working life in these studies, including estimates for the construction industry [Fosbroke et al., 1997], in which: $WLTR = (1-(1-R)^{y}) \times 100$

- **R** = probability of a worker having a work-related injury in a given year
- **1–R** = probability of a worker *not* having a work-related injury in a given year
- ^{y} = years of exposure to work-related injury
- **$(1-R)^{y}$** = probability of surviving ^{y} years without a work-related injury
- **$1-(1-R)^{y}$** = probability of having a work-related injury over ^{y} years of employment

For this current study, the above formula and tabulation methods were adopted assuming a working life for a construction worker would be 45 years, the same as the overall U.S. workforce considering the average age of construction workers was close to the overall U.S. workforce in 2010 [CPWR, 2013], and the trend of the aging workforce (BLS, 2012, Banerjee, 2001; Gendell, 2008).

The average annualized rate for 2003–2007 was used as the basis for estimating lifetime risk. This time period was selected for several reasons. Starting in 2003, the 1987 Standard Industrial Classification (SIC) system had been replaced with the North American Industry Classification System (NAICS; BLS, 2010), while the 1990 Census Occupational Classification System switched to the 2000 Standard Occupational Classification System (SOC; BLS, 2004a). In addition, OSHA had changed reporting criteria for nonfatal injuries and illnesses since 2002. Using data from 2003 onward allows multiple years of data to be more comparable and easily combined by the same classifications. In addition, by using the average data from a 5-year period from 2003 to 2007, yearly data fluctuations are minimized and the reliability in deriving "lifetime risk" estimates increases. Furthermore, this time period was selected because both fatal and nonfatal injury rates have declined significantly over past decades and estimates using this time period would better capture the current risk in construction. If data from 1992 were included, the estimated risk would be higher and the effects of recent construction interventions would not be accounted for in the computations. Finally, the end date of 2007 was used to avoid distortions resulting from the national economic crisis that began in 2007 and worsened through 2010 (National Bureau of Economic Research, 2010), which led to a steep decline in employment and significant demographic distortions in the construction labor force. In particular, Hispanic, non-union, and younger workers were disproportionately affected [CPWR, 2013a] and therefore, injury data during the economic downturn may not reflect the real risk in the construction industry.

To standardize reporting, risks were measured as the number of injuries per 100 FTEs (assuming 2,000 hr worked per year; Northwood, 2009). Given injury variances among construction subgroups [Dong et al., 2010a,b; CPWR, 2013], injury risk was stratified by occupation and Hispanic ethnicity. Because non-Hispanic is a broader category including other minorities (e.g., Asian, black, etc.), White, non-Hispanic was determined to be the best comparison group for Hispanic workers to estimate ethnic disparities in construction. Inclusion of other ethnic groups in the comparison may add little statistical strength and increase variance because of the small number of workers in each of these groups.

Considering substantial evidence that nonfatal injuries are underreported, [Leigh et al., 2004; Rosenman et al., 2006; Friedman and Forst, 2007; Boden and Ozonoff, 2008; Committee on Education and Labor, 2008; Ruser, 2008; Boden and Ozonoff, 2010; Oleinick and Zaidman, 2010], particularly in the construction industry [Welch et al., 2007; Dong et al., 2011], risks were adjusted assuming that the trends of both fatal and nonfatal injuries would be similar [Leigh et al., 2004; Dong et al., 2011]. The adjustment used the year 1992 as the basis for two reasons. One of the reasons is that beginning in 1992, the BLS has collected a comprehensive count of work-related deaths in the CFOI

(BLS, 2004b). The second reason is that the increase in Hispanic employment started in the early 1990s, and the number of nonfatal injuries was less inaccurate then considering that recent studies found that nonfatal injuries among Hispanic construction workers are more likely to be underreported (Dong et al., 2010a, 2010b, 2011). This method assumed that a shift in the organization of work and interventions would have similar effects on both fatal and nonfatal injuries in construction over time.

Based on these assumptions, if the number of nonfatal injuries reported in 1992 (n = 17,715) was accurate and increased at the same rate as fatal injuries, the number of nonfatal injuries among Hispanic construction workers in 2006 would be around 59,000 (17,715*3.3) instead of the 33,930 cases reported (Appendix I). This calculation did not take into account the changes in OSHA injury and illness record-keeping rules during the time period. In addition, the rates of DAFW injuries were also adjusted for missing values for ethnicity (about 25%) in the SOII as well as the difference in FTEs between estimates from the CPS data and the numbers from the SOII published by the BLS (about 10%; CPWR, 2008). Additionally, 95% confidence intervals (CIs) of lifetime risk were computed based on the upper and lower FTE estimates (Appendices II and III). Since falls remain the leading cause of death in the construction industry, the risk of fatal falls were examined in detail.

RESULTS

Fatal Injuries

Between 2003 and 2007, a total of 6,228 construction workers died at job sites (Table I). If the risk remained the same, the death rate would be 0.506% over a 45-year working life in construction; or about 1 death per 200 full-time construction workers. Furthermore, falls are the leading cause of death in construction. Therefore, the lifetime risk of fall-related fatalities would be 17% for construction workers on average.

Table II summarizes the lifetime risk of traumatic fatalities in the construction industry and the differences in cause-specific fatality risks for Hispanic and white, non-Hispanic workers. Over a 45-year working life, 0.56 fatalities would occur per 100 full-time Hispanic workers (95% CI: 0.55–0.59%). The lifetime risk of fatalities for Hispanic workers would be about 20% higher than for white, non-Hispanic workers (0.56% vs. 0.47%); the disparity would be primarily for falls (0.22% vs. 0.15%) and transportation-related injuries (0.13% vs. 0.08%). The lifetime risk of fall-related fatalities would be about 47% higher for Hispanic construction workers than for their white, non-Hispanic counterparts. However, it appears that Hispanic construction workers would have a lower risk of contact with objects/equipment compared to their white, non-Hispanic counterparts (0.11% vs. 0.14%).

Table III shows that the risk of fatalities among construction trades would vary greatly, ranging from 0.24% among drywall installers to 3.11% among ironworkers. The difference between these two occupations was more than 10-fold. Similarly, the risk of fatal falls differed by trade (Table IV). Ironworkers, roofers, and power installers had the greatest risks (1.93, 1.16, and 0.54%); which were about 20, 12, and 6 times higher than for a construction manager (0.09%), respectively. Truck drivers (0.04%) and operating engineers (0.03%), who typically drive large movable equipment, had a lower risk of fatal falls. Only a small proportion of construction fatalities were among public sector employees. Analyses of fatality trends with and without the public sector in construction were similar, and thus were not reported separately.

TABLE I. Lifetime Risk[a] of Fatalities by Leading Causes in Construction

		Annual rate[a]			Lifetime risk[a]		
			95% Confidence interval			95% Confidence interval	
Leading causes	Deaths (2003–2007)	Point estimate	Lower	Upper	Point estimate	Lower	Upper
Falls	2,095	0.00379	0.00354	0.00408	0.17	0.16	0.18
Transportation accidents	1,679	0.00304	0.00284	0.00327	0.14	0.13	0.15
Contact with objects and equipment	1,195	0.00216	0.00202	0.00233	0.10	0.09	0.10
Exposure to harmful substances or environments	897	0.00162	0.00152	0.00175	0.07	0.07	0.08
Assaults and violent acts	188	0.00034	0.00032	0.00037	0.02	0.01	0.02
Fires and explosions	160	0.00029	0.00027	0.00031	0.01	0.01	0.01
All causes	6,228	0.01127	0.01052	0.01213	0.51	0.47	0.54

Source: Fatal injury data were generated by the authors with restricted access to BLS CFOI data.
[a]Deaths per 100 FTEs. The lifetime risk assumes a working time of 45 years.

TABLE II. Lifetime Risk[a] of Fatalities by Leading Causes and Hispanic Ethnicity in Construction

	Hispanic				White, non-Hispanic			
			95% Confidence interval				95% Confidence interval	
Leading Causes	Deaths (2003–2007)	Lifetime Risk[a]	Lower	Upper	Deaths (2003–2007)	Lifetime risk[a]	Lower	Upper
Falls	626	0.22	0.22	0.23	1,284	0.15	0.15	0.15
Transportation Incidents	351	0.13	0.12	0.13	719	0.08	0.08	0.09
Contact with Objects and Equipment	320	0.11	0.11	0.12	1,179	0.14	0.14	0.14
Exposure to Harmful Substances or Environments	210	0.08	0.07	0.08	594	0.07	0.07	0.07
Assaults and Violent Acts	37	0.01	0.01	0.01	126	0.01	0.01	0.02
Fires and Explosions	31	0.01	0.01	0.01	103	0.01	0.01	0.01
All Causes	1,579	0.56	0.55	0.59	4,014	0.47	0.47	0.48

Source: Fatal injury data were generated by the authors with restricted access to BLS CFOI data.
[a]Deaths per 100 FTEs. The lifetime risk assumes a working time of 45 years.

Nonfatal Injuries With Days Away From Work

Table V displays the risk of nonfatal injuries involving days away from work in construction. Between 2003 and 2007, the annual rate of DAFW injuries was 2.3% (95% CI: 2.24–2.37%). The lifetime risk of DAFW injuries based on SOII data was about 65% for the overall construction industry, and the adjusted risk was 78%. Unadjusted injury rates for white, non-Hispanic workers were higher than for

TABLE III. Lifetime Risk[a] of Trade-Specific Fatalities in Construction

			95% Confidence interval	
Trade	Deaths (2003–2007)	Lifetime risk[a]	Lower	Upper
Ironworker	170	3.11	2.44	4.31
Power installer	83	2.61	1.88	4.26
Roofer	354	1.42	1.26	1.64
Truck driver	247	1.10	0.97	1.27
Laborer	1,538	1.04	0.99	1.10
Welder	97	0.88	0.73	1.12
Helper	90	0.75	0.63	0.93
Operating engineer	265	0.73	0.66	0.82
Foreman	494	0.49	0.46	0.52
Electrician	345	0.49	0.45	0.53
Construction manager	458	0.43	0.41	0.46
Sheet metal worker	34	0.42	0.34	0.54
Brickmason	90	0.39	0.34	0.45
Heating	116	0.37	0.33	0.42
Painter	231	0.37	0.34	0.40
Plumber	179	0.32	0.29	0.35
Carpenter	526	0.32	0.30	0.33
Drywall	60	0.24	0.21	0.27
All construction	6,228	0.506	0.472	0.544

Source: Fatal injury data were generated by the authors with restricted access to BLS CFOI data.
[a]Deaths per 100 FTEs. The lifetime risk assumes a working time of 45 years.

TABLE IV. Lifetime Risk[a] of Trade-Specific Fall Fatalities in Construction

			95% Confidence interval	
Trade	Deaths (2003–2007)	Lifetime risk[a]	Lower	Upper
Ironworker	105	1.93	1.51	2.68
Roofer	288	1.16	1.02	1.33
Power installer	17	0.54	0.39	0.89
Laborer	481	0.33	0.31	0.34
Welder	33	0.30	0.25	0.38
Sheet metal worker	19	0.23	0.19	0.30
Helper	25	0.21	0.18	0.26
Brickmason	132	0.21	0.18	0.24
Painter	48	0.21	0.19	0.23
Carpenter	313	0.19	0.18	0.20
Drywall	41	0.16	0.14	0.19
Foreman	141	0.14	0.13	0.15
Heating	39	0.13	0.11	0.14
Electrician	80	0.11	0.11	0.12
Construction manager	98	0.09	0.09	0.10
Plumber	25	0.04	0.04	0.05
Truck driver	9	0.04	0.04	0.05
Operating engineer	9	0.03	0.02	0.03
All construction	2,095	0.17	0.16	0.18

Source: Fatal injury data were generated by the authors with restricted access to BLS CFOI data.
[a]Deaths per 100 FTEs. The lifetime risk assumes a working time of 45 years.

TABLE V. Lifetime Risk[a] of Nonfatal Injuries Involving Days Away from Work (DAFW)

		Annual rate of DAFW injuries[a]			Lifetime risk of DAFW injuries[b]		
			95% Confidence interval			95% Confidence interval	
Variable	DAFW Injuries (2003–2007)	Point estimate	Lower	Upper	Point estimate	Lower	Upper
Cause							
Contact with object or equipment	267,960	0.819	0.797	0.842	37.06	36.27	37.89
Overexertion	139,590	0.427	0.415	0.439	21.39	20.87	21.92
Fall to lower level	101,080	0.309	0.301	0.318	15.98	15.58	16.39
Fall on same level	63,910	0.195	0.190	0.201	10.42	10.15	10.7
Transportation incidents	29,500	0.090	0.088	0.093	4.95	4.82	5.08
Exposed to harmful substance	26,570	0.081	0.079	0.084	4.47	4.35	4.59
Slip, trip, loss of balance—without fall	22,100	0.068	0.066	0.069	3.73	3.63	3.83
Repetitive motion	12,650	0.039	0.038	0.040	2.15	2.09	2.21
Ethnicity							
White, non-Hispanic	427,470	2.442	2.393	2.475	72.84	72.24	74.35
Hispanic	146,920	2.064	1.958	2.113	84.05	83.55	85.29
All construction	754,220	2.305	2.243	2.370	77.84	76.91	78.78

The number of injuries includes less than 3% of occupational illnesses and excludes the self-employed and the public sector.
[a]Injuries per 100 FTEs. The estimates were adjusted for rates by ethnicity due to missing information on ethnicity for some cases.
[b]Injuries per 100 FTEs. The lifetime risk assumes a working time of 45 years.

Hispanic workers, while the opposite was found after adjustments according to the CFOI data. After adjustment, the results indicate that about 37% of construction workers can experience serious injuries from contact with equipment, while 21% experience serious injuries due to overexertion during their entire working life.

Trade-specific injury risks also indicated that rates are higher after adjustment (Table VI). In general, trade-specific risks had a wide range. Helpers, an occupation with the least skills and training requirements, had the highest injury risk. Overall, construction trades workers had a risk of injury at least three times greater than the risk for construction managers.

DISCUSSION

Using multiple years of national data, we estimated that working in construction for 45 years, the risk of fatal injuries is approximately 1 death per 200 FTEs, and the risk of serious (DAFW) injuries is as high as 78%. The findings suggest that risks in construction remain high given that OSHA considers a lifetime risk of 1 death in 1,000 workers to be a significant level of risk [Stayner, 1992; Adkins, 1993].

The estimates indicate that there are significant variations between occupations. The lifetime risk of fatal injuries for ironworkers is about 10 times the risk for plumbers. The results also show that the unadjusted nonfatal injury risk for Hispanic workers was lower than for white, non-Hispanic workers, while Hispanic workers had a higher

TABLE VI. Lifetime Risk[a] of Trade-Specific Injuries Involving Days Away from Work (DAFW) in Construction

				95% Confidence interval	
Trade	Injuries (2003–2007)	Lifetime risk[a]	Adjusted lifetime risk[a]	Lower	Upper
Helper	28,160	95.88	98.03	96.11	99.31
Sheet metal worker	13,850	91.66	94.92	90.73	98.15
Ironworker	8,370	89.99	93.67	87.77	98.21
Laborer	173,030	81.91	87.69	86.22	89.14
Truck driver	20,950	75.73	81.83	77.10	86.78
Carpenter	121,010	73.05	79.39	77.51	81.32
Heating	26,050	72.11	78.30	74.05	82.81
Roofer	19,720	69.75	76.90	72.12	82.06
Plumber	43,790	69.62	76.10	72.84	79.56
Electrician	47,290	62.02	68.55	65.58	71.75
Power installer	2,120	60.02	66.55	53.85	84.69
Welder	7,520	59.55	66.40	59.03	75.39
Brickmason	12,260	57.61	64.72	59.19	71.19
Operating engineer	18,680	56.66	63.20	58.76	68.24
Drywall	12,150	53.21	60.84	55.75	66.8
Foreman	37,710	52.83	59.26	56.29	62.53
Painter	16,530	38.95	45.47	42.26	49.19
Construction manager	6,680	12.74	16.64	15.35	18.16

The number of injuries includes less than 3% of occupational illnesses and excludes the self-employed and the public sector.
[a]Injuries per 100 FTEs. The lifetime risk assumes a working time of 45 years.

fatal injury risk than white, non-Hispanic workers (see Tables II and IV). The findings confirm previous reports on underreporting of nonfatal injuries [Leigh et al., 2004; Rosenman et al., 2006; Welch et al., 2007; Dong et al., 2010a, 2011]. Reasons for underreporting differ at the organizational and individual level (Pransky et al., 1999; Probst et al., 2008; Dong et al., 2011). In general, companies with a poor safety climate had significantly higher rates of underreporting than companies with positive safety climate (Probst et al., 2008). Underreporting may be more common among Hispanic construction workers since they are more likely to be employed by small businesses, which tend to have worse health and safety records [Nelson et al., 1997; Okun et al., 2001; Dong et al., 2011]. Other obstacles to injury reporting among Hispanic workers, particularly new Hispanic immigrants, include lack of English proficiency, being unfamiliar with the workers' compensation system, and fear of negative consequences (e.g., losing their job) [Menzel and Gutierrez, 2010; Dong et al., 2013; Moore et al., 2013].

As with any study, this study has both strengths and limitations. A major strength was the use of nationally representative data for fatal and nonfatal injuries that had a good representation of construction trades by race/ethnicity. The traditional way of estimating occupational risk is using cross-sectional data on an annualized basis, which tends to understate risk [Robinson, 1986]. Estimating occupational risk based on the entire working life presents a more complete picture than a snapshot, and is relatively easy for people to understand, which may help young workers to consider safety and health risks when they make choices about jobs and careers in the construction industry, as well as inform policymakers regarding research and prevention priorities and options. Additionally, ethnic disparities in fatal and nonfatal injuries are more evident when presented in terms of lifetime risk as opposed to an annual rate.

A principal limitation in expressing risk based on lifetime experience was the assumption of constant injury and fatality rates to derive risk over 45 years, which does not account for potential changes in injury rates across workers' lifespans. In most occupational settings, safety and health performance has improved and risks have declined over time. This is also true in the construction industry. If future injury or fatality rates are substantially lower than those found for 2003–2007, this study will overestimate lifetime risks in construction. Similarly, this study reported leading causes of fatalities based on the data during the study period. However, some leading causes may decline more than others. For instance, between 1992 and 2009, rates of deaths from falls and electrocutions declined respectively by 21.3% and 54.9%, and overall deaths rates for the two most affected trades, electrical installation workers and ironworkers, declined by over 70% [CPWR, 2011]. Therefore, the use of 2003–2007 rates may represent conservative lifetime risk estimates. Additionally, the denominators based on self-reported hours worked are more likely to be overestimated, which would lead to underestimation of risks. It should also note that these estimates are average risks and should not be interpreted as individual risks.

The estimated lifetime risk of nonfatal injuries is less accurate than fatal injuries even after adjustment. The ethnic information was missing for many nonfatal cases. The risk assessments were adjusted assuming the missing information was random and normally distributed for all ethnicities. However, we lack the data to verify this assumption. In addition, while the 1992 data was used as the basis to adjust the estimates for risks of nonfatal injuries, it is difficult to know whether the nonfatal and fatal injury data were equally accurate at that time. If any of the assumptions were different from the actual situations, the lifetime risk estimates could be either overestimated or underestimated. Also, this study only focused on work-related injuries because only less than 3% of the construction cases in the SOII data were illnesses. Moreover, a worker may experience multiple injuries from different causes during their working life, while the model used for this study only counted the probability of a one-time injury. Thus, the risk of nonfatal injuries may be underestimated for some high-risk construction trades susceptible to multiple injuries over time.

CONCLUSION

This study estimated lifetime risk of fatal and nonfatal injuries among construction workers assuming a working life of 45 years. The results indicate that the lifetime risk of nonfatal injuries among construction workers is about 78% (78 per 100 FTEs), and 1 death per 200 FTEs. The risks remain high in construction given that OSHA considers 1 death per 1,000 workers as a high-level risk.

To the extent that occupational safety and health policies are driven by occupational injury and illness (OII) data, policy options could differ if lifetime risks were considered. Future interventions and efforts should focus on high-risk occupations, such as ironworkers and roofers, as well as Hispanic workers and leading causes of work-related deaths such as falls to a lower level.

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APPENDIX I. Fatal and DAFW Injuries in the U.S. Construction Industry, 1992–2010

	Hispanic Construction Workers				Total Construction			
Year	Deaths	1992 (Baseline), %	DAFW Injuries	1992 (Baseline), %	Deaths	1992 (Baseline), %	DAFW Injuries	1992 (Baseline), %
1992	108	100.0	17,700	100.0	963	100.0	209,600	100.0
1993	109	100.9	18,000	101.7	971	100.8	204,800	97.7
1994	116	107.4	17,700	100.1	1,077	111.8	218,800	104.4
1995	146	135.2	19,000	107.2	1,098	114.0	190,600	90.9
1996	137	126.9	19,700	111.3	1,095	113.7	182,300	87.0
1997	167	154.6	21,300	120.5	1,136	118.0	189,900	90.6
1998	215	199.1	23,000	129.7	1,207	125.3	178,300	85.1
1999	225	208.3	29000	162.2	1,228	127.5	193,800	92.5
2000	278	257.4	26,000	149.3	1,183	122.9	194,400	92.8
2001	282	261.1	29,700	167.7	1,264	131.3	185,700	88.60
2002	245	226.9	26,000	146.7	1,153	119.7	163,700	78.10
2003	261	241.7	26,800	151.0	1,171	121.6	155,400	74.1
2004	312	288.9	28,000	158.0	1,278	132.7	153,200	73.09
2005	321	297.2	32,800	185.0	1,243	129.1	157,100	74.95
2006	354	327.8	33,900	191.5	1,297	134.7	153,200	73.09
2007	317	293.5	25,500	143.8	1,239	128.7	135,400	64.58
2008	253	234.3	25,000	141.1	1,016	105.5	120,200	57.35
2009	222	205.6	18,000	101.6	879	91.3	92,500	44.13
2010	182	168.5	13,000	73.38	802	83.3	75,000	35.78

DAFW, days away from work.

Source: U.S. Bureau Labor Statistics, Census of Fatal Occupational Injuries, Survey of Occupational Injuries and Illnesses,http://www.bls.gov/iif/

APPENDIX II. Estimated Number of Full-Time Employees (FTEs) in Construction, 2003–2007 (All Employment)

	Number of FTEs					Lower 95% CI					Upper 95% CI				
Occupation	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**
Brickmason	192,779	208,910	197,794	216,525	218,003	165,147	178,875	170,730	187,442	187,053	220,418	238,948	224,858	245,604	248,953
Carpenter	1,332,136	1,500,285	1,553,681	1,570,559	1,537,908	1,266,449	1,429,182	1,481,798	1,497,711	1,465,426	1,397,823	1,571,383	1,625,571	1,643,409	1,610,389
Manager	694,542	906,036	923,676	1,041,366	1,204,076	642,259	845,610	864,553	978,193	1,135,987	746,819	966,460	982,796	1,104,535	1,272,162
Drywall	204,403	202,749	230,627	281,914	226,593	175,696	174,041	201,973	249,033	196,828	233,112	231,457	259,281	314,791	256,364
Electrician	557,945	611,089	666,521	658,716	690,673	512,690	561,944	616,285	609,511	638,493	603,201	660,227	716,764	707,919	742,859
Foreman	837,972	874,732	964,240	956,835	889,568	782,148	817,110	903,529	896,578	830,192	893,798	932,358	1,024,951	1,017,093	948,946
Heating	218,397	276,641	270,536	310,446	325,833	189,955	243,354	237,902	275,364	289,431	246,842	309,936	303,166	345,522	362,236
Helper	103,573	101,697	117,939	113,811	98,641	83,531	81,616	95,625	92,557	78,440	123,626	121,768	140,258	135,061	118,848
Ironworker	55,201	40,300	46,719	41,771	57,960	39,696	28,681	33,753	29,163	42,420	70,707	51,921	59,685	54,382	73,511
Laborer	995,241	1,120,022	1,349,282	1,534,415	1,628,334	936,146	1,056,196	1,279,926	1,460,906	1,552,100	1,054,327	1,183,854	1,418,643	1,607,926	1,704,568
Operating engineer	313,940	286,726	334,329	361,577	331,650	279,070	253,000	298,513	324,949	295,843	348,810	320,457	370,148	398,208	367,459
Painter	537,566	580,587	564,665	564,061	593,047	492,428	532,974	518,127	517,762	544,948	582,700	628,195	611,197	610,354	641,139
Plumber	449,555	482,183	481,241	552,706	578,968	408,948	438,778	437,778	506,200	531,303	490,155	525,591	524,699	599,201	626,635
Power installer	30,804	31,919	31,562	23,026	23,889	19,514	19,900	19,605	12,955	13,858	42,089	43,940	43,517	33,095	33,926
Roofer	189,601	229,656	249,669	214,368	228,473	163,073	199,457	218,253	185,359	198,675	216,130	259,861	281,084	243,381	258,270
Sheet metal worker	74,290	91,206	75,035	68,369	57,532	58,383	71,501	58,134	51,726	42,572	90,201	110,906	91,932	85,020	72,487
Truck driver	203,778	210,791	186,053	203,563	203,953	175,916	182,353	159,985	176,044	175,066	231,646	239,225	212,116	231,081	232,837
Welder	86,520	112,246	110,831	91,734	92,645	68,494	87,805	89,343	71,983	71,864	104,550	136,685	132,324	111,492	113,425
Ethnicity															
White, non-Hispanic	7,111,102	7,605,268	7,716,154	7,894,791	7,875,657	7,017,562	7,507,054	7,616,019	7,791,500	7,769,877	7,204,646	7,703,481	7,816,297	7,998,076	7,981,434
Hispanic	2,017,211	2,194,371	2,510,882	2,907,366	2,911,849	1,932,590	2,105,841	2,419,705	2,811,958	2,814,110	2,101,834	2,282,902	2,602,051	3,002,782	3,009,586
All construction	9,971,414	10,670,158	11,158,120	11,702,692	11,763,594	9,236,002	9,887,299	10,370,926	10,901,573	10,949,283	10,706,836	11,453,017	11,945,303	12,503,800	12,577,929

Source: U.S. Bureau Labor Statistics, Current Population Survey, 2003–2007. Calculations by the authors.

APPENDIX III. Estimated Number of Full-time Employees (FTEs) in Construction, 2003–2007 (Private Wage-and-Salary Workers)

	Number of FTEs					Lower 95% CI					Upper 95% CI				
Trades	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**	**2003**	**2004**	**2005**	**2006**	**2007**
Brickmason	145,462	152,046	158,075	172,534	158,310	121,476	126,564	133,725	146,295	131,944	169,445	177,525	182,425	198,774	184,677
Carpenter	909,728	1,014,226	1,072,745	1,065,009	1,044,793	855,329	955,490	1,012,300	1,005,050	984,678	964,125	1,072,968	1,133,186	1,124,964	1,104,907
Manager	371,762	466,436	462,858	515,052	564,647	333,223	422,545	419,815	469,707	516,627	410,302	510,326	505,903	560,393	612,663
Drywall	145,834	151,210	182,660	219,540	180,484	121,562	126,155	157,000	190,615	154,016	170,108	176,267	208,321	248,466	206,955
Electrician	475,735	521,385	555,598	566,751	572,908	434,122	476,241	510,098	521,223	525,276	517,344	566,530	601,096	612,276	620,538
Foreman	496,964	507,957	572,911	578,183	603,882	452,975	463,904	525,274	531,011	554,236	540,951	552,011	620,548	625,355	653,535
Heating	176,941	215,445	211,947	256,448	267,646	151,590	186,716	183,561	224,626	234,987	202,296	244,171	240,336	288,267	300,311
Helper	101,502	96,841	116,108	101,363	83,095	81,704	77,149	93,968	81,222	64,705	121,298	116,539	138,253	121,509	101,489
Ironworker	44,272	28,876	41,761	36,342	52,199	30,677	19,301	29,532	24,513	37,574	57,862	38,450	53,991	48,165	66,826
Laborer	827,621	949,554	1,157,137	1,320,700	1,369,003	774,095	891,215	1,093,600	1,253,473	1,299,770	881,145	1,007,890	1,220,678	1,387,934	1,438,232
Operatingengineer	243,672	208,209	253,218	259,960	264,798	212,453	178,722	221,354	228,804	232,334	274,891	237,692	285,084	291,115	297,262
Painter	356,345	361,842	345,892	374,519	383,140	318,669	324,693	309,162	336,568	343,931	394,022	398,993	382,622	412,470	422,344
Plumber	355,529	372,653	395,814	447,931	459,039	319,774	334,536	356,459	406,553	417,156	391,278	410,769	435,169	489,309	500,919
Power installer	28,927	29,442	26,182	23,026	19,833	17,819	17,777	15,322	12,960	11,113	40,036	41,102	37,047	33,091	28,548
Roofer	145,264	189,461	208,293	176,199	192,164	122,481	162,111	179,812	150,132	164,855	168,048	216,808	236,773	202,262	219,477
Sheet metal	69,825	76,801	63,810	55,406	46,717	54,384	59,433	48,303	40,824	33,143	85,268	94,169	79,319	69,984	60,291
Truck driver	157,337	169,475	145,412	176,272	171,144	132,495	143,728	122,241	150,336	144,483	182,182	195,219	168,580	202,211	197,808
Welder	77,633	106,298	106,755	83,504	83,427	60,571	82,355	85,706	64,553	64,027	94,690	130,239	127,809	102,461	102,829
Ethnicity															
White, non-Hispanic	4,802,582	5,112,532	5,288,581	5,378,823	5,390,886	4,721,258	5,027,266	5,200,785	5,288,450	5,298,258	4,883,911	5,197,796	5,376,377	5,469,199	5,483,519
Hispanic	1,731,228	1,824,812	2,150,922	2,504,520	2,476,494	1,655,383	1,746,390	2,069,065	2,419,040	2,389,252	1,807,073	1,903,235	2,232,775	2,590,002	2,563,735
Total private wage–and-salary workers in construction	7,127,622	7,577,780	8,115,347	8,526,333	8,588,409	6,494,568	6,908,844	7,434,096	7,833,389	7,884,812	7,760,669	8,246,709	8,796,606	9,219,268	9,292,032

Source: U.S. Bureau Labor Statistics, Current Population Survey, 2003–2007. Calculations by the authors.