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Trends of Occupational Fatalities Involving Machines, United States, 1992–2010

Suzanne M. Marsh, MPA* and **David E. Fosbroke, MSF**

National Institute for Occupational Safety and Health, Division of Safety Research, Surveillance and Field Investigations Branch, Morgantown, West Virginia

Abstract

Background—This paper describes trends of occupational machine-related fatalities from 1992–2010. We examine temporal patterns by worker demographics, machine types (e.g., stationary, mobile), and industries.

Methods—We analyzed fatalities from Census of Fatal Occupational Injuries data provided by the Bureau of Labor Statistics to the National Institute for Occupational Safety and Health. We used injury source to identify machine-related incidents and Poisson regression to assess trends over the 19-year period.

Results—There was an average annual decrease of 2.8% in overall machine-related fatality rates from 1992 through 2010. Mobile machine-related fatality rates decreased an average of 2.6% annually and stationary machine-related rates decreased an average of 3.5% annually. Groups that continued to be at high risk included older workers; self-employed; and workers in agriculture/forestry/fishing, construction, and mining.

Conclusion—Addressing dangers posed by tractors, excavators, and other mobile machines needs to continue. High-risk worker groups should receive targeted information on machine safety.

Keywords

occupational fatal injuries; CFOI; machinery; stationary; mobile

INTRODUCTION

Machines are a critical part of our lives. They take various forms and allow people to work with less effort and improve production efficiency. However, without proper safeguarding

*Correspondence to: Suzanne M. Marsh, MPA, National Institute for Occupational Safety and Health, Division of Safety Research, 1095 Willowdale Road., MS 1808, Morgantown, West Virginia 26505. smm2@cdc.gov.

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Impact on Industry: This paper updates fatal injury statistics on machine-related fatal injury to guide safety and health professionals' injury prevention efforts, whether their focus is a particular industry, worker population, or machine type.

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and controls, physical contact with machines, and powered equipment can result in severe workplace injuries and deaths.

Since its establishment in 1971, the National Institute for Occupational Safety and Health (NIOSH) has played a lead role in conducting machine safety research and in identifying the most hazardous machines affecting the U.S. workforce [Etherton and Myers, 1990]. Etherton and Myers [1990] found that incidents involving tractors and forklifts accounted for the largest number of occupational machine-related fatalities based on data from 1980–1985 from the National Traumatic Occupational Fatalities (NTOF) database. More rigorous analyses of NTOF suggested that machines were the second leading cause of occupational fatalities in the U.S., accounting for 14% of all work-related deaths from 1980 through 1989 [Pratt et al., 1996], and the second or third cause of occupational fatalities in the U.S. from 1980 through 1998 [NIOSH, 2004].

Workplace and worker safety has improved with advancements in regulations, consensus standards, and best work practices [CDC, 1999]. The question is whether we have made improvements in the safety of persons working in or around machines a little over forty years since the passage of the Occupational Safety and Health (OSH) Act of 1970 (Public Law 91–596) and the creation of agencies like the Occupational Safety and Health Administration (OSHA), Mine Safety and Health Administration, and NIOSH. While overall fatality numbers and rates have generally decreased in recent decades [BLS, 2014], many workplaces are using machines that potentially introduce new risks [Etherton, 2007], and statistics suggest that machines (including forklifts and tractors) still account for 13% of all work-related deaths [BLS, 2014]. To determine if the incidence and circumstances have changed, we examined occupational machine-related fatalities for 1992–2010 and describe these deaths by temporal pattern for worker demographics, machine type (i.e., stationary versus mobile), and industry sector.

METHODS

Fatality Data

We analyzed occupational fatality data for the years 1992 through 2010 using restricted-access research files from the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI).[1] BLS collects these data through a state and federal cooperative arrangement from all 50 states and the District of Columbia [BLS, 2012a]. To identify deaths for CFOI, states obtain information from multiple federal, state, and local source documents including death certificates, police reports, and Workers' Compensation reports [BLS, 2012a]. For a fatal work-related injury to be included in CFOI, the decedent must have been employed at the time of the event and engaged in a legal work activity or present at or traveling between work sites as a job requirement. Data are collected for all public and private sector workers regardless of worker age or establishment size [BLS, 2012a]. These data include volunteers performing the same duties as paid employees (e.g.,

[1]The analysis of CFOI was conducted with restricted-access BLS datasets that are provided to the NIOSH Division of Safety Research under a memorandum of understanding. The views expressed here do not necessarily reflect the views of the BLS.

volunteer fire fighters). Fatalities occurring during a normal commute to or from work and deaths related to occupational illnesses (e.g., lung disease) are excluded.

Industry Classification

Since its inception, the BLS has used multiple coding systems to code industry information in CFOI. The Standard Industrial Classification (SIC) Manual [OMB, 1987] was used for data years 1992 through 2002, and the North American Industrial Classification System (NAICS) [OMB, 2002] was used for data years 2003 through 2010. The switch from SIC to NAICS resulted in profound differences due to several industry sectors being redefined and establishments being shifted from sector to sector. For example, logging was reclassified from manufacturing to agriculture/forestry/fishing, certain computer stores were reclassified from wholesale to retail based on how the stores conduct business, and local trucking establishments were split and classified as both transportation/warehousing and administrative and support and waste. Because of these and other significant shifts and since BLS classified the switch from SIC to NAICS as a break in series [BLS, 2012a], all analyses by industry for this study were limited to 2003 through 2010 data.

Case Identification and Groupings

The source of injury in CFOI identifies the object, substance, or person that generated the injury, or that contributed to the incident [BLS, 2012a]. BLS coded source information based on the BLS-developed Occupational Injury and Illness Classification System (OIICS) version 1.01 [BLS, 2007]. We used the OIICS source codes to identify cases for this study where the primary source of injury was a machine. Machines were categorized into two separate groups, mobile or stationary, based on the OIICS source of injury (Table I). Although the OIICS category for machines (OIICS source code = “3”) does not include forklifts and tractors (OIICS source code = “85”), they were included as machines in this analysis.

Rate Calculations

Fatality rates were computed using employment estimates derived from the BLS Current Population Survey (CPS), a monthly household survey that includes data on sex, age, employment, industry, and other work-related characteristics [BLS, 2012b]. The CPS provides information on the U.S. civilian, non-institutionalized population aged 15 years old or older and includes wage and salary workers, self-employed, part-time workers, and unpaid workers in family-owned businesses (e.g., farms). The CPS collects the number of hours worked from all respondents including those holding multiple jobs. Thus, total hours worked reflects hours worked for all jobs held during the survey week. Average annual rates were calculated as the total number of fatalities divided by total hours worked for all jobs for each of the characteristics of interest (i.e., sex, age, worker type, and industry) and are reported as the number of fatal work injuries per 100,000 full-time equivalent (FTE). We report fatality numbers for all ages, as CFOI includes occupational fatality data for all age groups, but rates are restricted to workers aged 15 years and older due to availability in CPS. A review of detailed fatality rates for workers aged 15–24, 25–34, 35–44, and 45–54 indicated that rates for all four age groups were similar. Thus, workers aged 15–54 were combined and annual rates were calculated for this single group for the purposes of this analysis. Finally, because totals for hours worked were not available for self-employed workers for 1992 through 1993 from the CPS, rates for self-employed are presented for 1994–2010. The number of hours worked for self-employed were only available for primary job worked.

Trend Analysis

Poisson regression was used to assess trends in machine-related fatality rates. Poisson regression models were conducted using the SAS *GENMOD* procedure available from the SAS Institute (version 9.3) [SAS, 2011]. Average annual changes (in terms of a percentage decrease/increase from the preceding year) in rates of workplace fatalities with 95% confidence intervals were produced by exponentiating the parameters from the regressions. The scale parameter in SAS *GENMOD* was set to “p” to account for under/overdispersion in the models [SAS, 2011].

RESULTS

Trend Overview

There were 14,625 occupational fatalities involving machinery from 1992 to 2010, resulting in an annual average of 770 deaths. The total number of machine-related deaths declined 32% during the 19-year period. The number of deaths from mobile machinery declined 22% compared to a 56% decline in the number of deaths from stationary machinery (Fig. 1a).

The overall machine-related annual average fatality rate for the 19-year period was 0.6 per 100,000 FTE. There was an average annual decrease of 2.8% (95% confidence interval (CI): 2.4%, 3.2%) in the overall machine-related fatality rates per 100,000 FTE from 1992 through 2010 (Figure 1b). Similar to the overall machine-related fatality rates, there was an average annual decrease of 2.6% (95%CI: 2.1%, 3.0%) in fatality rates per 100,000 FTE from 1992 through 2010 for mobile machines and an average annual decrease of 3.5% (95%CI: 2.8%, 4.3%) for stationary machines (Fig. 1b).

By age group, workers 75 years and older had the highest overall annual average fatality rate (10.5/100,000 FTE) followed by those 65–74 (3.1), 55–64 (0.8), and <55 (0.4) for the 19-year period. Fatality rates decreased significantly for all four age groups over the 19-year period (Fig. 2). The largest average annual decreases were seen among workers 75 years and older (5.7%; 95%CI: 4.9%, 6.5%) and among workers 65 to 74 years old (5.5%; 95%CI: 4.5%, 6.5%).

Self-employed workers comprised 33% (4,831) of the total number of machine-related incidents. From 1994 to 2010, the self-employed had an overall annual average fatality rate of 1.7/100,000 FTE compared to the average annual fatality rate of 0.4/100,000 for workers who were not self-employed. There was an average annual decrease of 6.9% (95%CI: 6.1%, 7.7%) for self-employed workers (Fig. 3). The rate for workers who were not self-employed had an average annual decrease of 1.9% (95%CI: 1.1%, 2.7%).

An examination of the data for type of machine found that tractors (4,279 or 29%), forklifts (1,487 or 10%), excavating machines (1,078 or 7%), loaders (953 or 7%), and cranes (720 or

5%) were involved in the largest numbers of deaths. Machines with the highest average annual fatality rates per 100,000 FTE were the same; tractors had the highest rate (0.17/100,000 FTE), followed by forklifts (0.06), excavating machines (0.04), loaders (0.04), and cranes (0.03). The fatality rates per 100,000 FTE for these machines all generally decreased from 1992 through 2010 (Fig. 4). Rates for tractors, however, increased slightly between 2007 and 2010. Tractors (average annual decrease of 3.5%; 95% CI: 0.6%, 6.2%), loaders (average annual decrease of 1.8%; 95%CI: 1.0%, 2.6%), and cranes (average annual decrease of 3.7%; 95%CI: 1.6%, 5.8%) all had significant decreasing trends in fatality rates per 100,000 FTE. The decreases in fatality rates for forklifts (1.2% average annual decrease; 95%CI: −0.2%, 2.5%) and excavating machines (1.2% average annual decrease; 95%CI: −0.3%, 2.7%) were not significant.

Trends by Industry Sector

For the years 2003 to 2010, the industry sectors with the largest number of deaths were agriculture/forestry/fishing (2,063 deaths or 37% of all 5,579 machine-related deaths during this 8-year period), construction (1,204 or 22%), manufacturing (776 or 14%), and services (725 or 13%) (Table II). Industry sectors with the highest machine-related average annual occupational fatality rates per 100,000 FTE were agriculture/forestry/fishing (10.8), mining (3.5), and construction (1.4) (Table II). Although each of these three sectors had average annual machine-related fatality rates that were much higher than the overall 8-year period annual average rate of 0.5 per 100,000 FTE, the fatality rates generally declined in all industry sectors from 2003 through 2010 (Fig. 5). The average annual percentage decrease in trends by industry sector was only significant for construction (5.5%; 95%CI: 3.7%, 7.2%), manufacturing (6.6%; 95%CI: 1.6%, 11.3%), and mining (12.3%; 95%CI: 4.3%, 19.5%).

Fatality rates per 100,000 FTE were explored in greater detail for the three industries with the largest percentage of fatalities from 2003 through 2010: agriculture/forestry/fishing, construction, and manufacturing.

In the agriculture/forestry/fishing industry, almost 94% of machine-related fatalities involved mobile machines (Table II). The tractor-related fatality rate in this industry declined from 2003 through 2007, then increased through 2010 (Fig. 6). Tractor-related fatality rates for workers 75 years and older in agriculture/forestry/fishing (data not shown) were 4–8 times higher than the overall machine-related fatality rates in this industry, ranging from a high of 94.7 per 100,000 FTE in 2003 to 54.7 in 2010. The agriculture/forestry/fishing industry trends shown in Figure 6 were not significant.

Of the total machine-related fatalities in the construction industry, 78% involved mobile machines. The average annual percentage decrease in trends was significant for both mobile machine-related fatalities per 100,000 FTE (5.7%; 95%CI: 4.4%, 7.0%) and the overall machine-related fatalities per 100,000 FTE for the industry (5.5%; 95%CI: 3.7%, 7.2%) (Fig. 7). The annual rates per 100,000 FTE for stationary machines were much lower and the average annual percentage decrease was not significant (4.6%; 95%CI: −4.1%, 12.6%). A review of the trends in fatality rates per 100,000 FTE by detailed type of machine found that the rates fluctuated greatly from 2003 through 2010. The average annual percentage decrease in rates for excavating machines was significant (6.6%; 95%CI: 0.9%, 11.9%); however, the average annual percentage decrease in rates for road grading and surfacing machines (7.9%; 95%CI: −3.5%, 18.0%), cranes (3.4%; 95%CI: −10.7%, 15.7%), and loaders (6.9%; 95%CI: −2.9%, 15.8%) in the construction industry were not significant.

In the manufacturing industry, about 64% of the machine-related fatalities involved stationary machines in contrast to the agriculture and construction industries where mobile machinery was predominant (Table II). The overall average annual percentage decrease in rates for machine-related fatalities in manufacturing per 100,000 FTE was significant (6.6%; 95%CI: 1.6%, 11.3%) as were the average annual percentage decreases in rates for stationary machines (5.8%; 95%CI: 1.9%, 9.5%) and forklifts (8.2%; 95%CI: 0.8%, 15.1%) (Fig. 8). The average annual percentage decrease in rates for mobile machines, however, was not significant (8.0%; 95%CI: −0.07%, 15.4%).

DISCUSSION

In this study, we found that the number of machine-related deaths and the overall machine-related fatality rates per 100,000 FTE declined from 1992 to 2010. Rates for both mobile and stationary machines also declined during this period. Workers aged 65 years and older were at substantially elevated risk for machine-related deaths for the entire period. Moreover, while the rate of tractor-related deaths declined, tractors consistently had the highest fatality rate for the entire 19-year period.

Based on our study, agriculture/forestry/fishing sector workers were involved in the largest number of incidents and had the highest fatality rate per 100,000 FTE compared to other industry sectors. The fatality rate per 100,000 FTE of tractor-related deaths in the agriculture/forestry/fishing sector was consistently high from 2003 through 2010. In addition, workers 75 years and older in the agriculture/forestry/fishing sector had particularly high fatality rates per 100,000 FTE. Fatality rates from 2003 through 2010 were generally 4–8 times higher than the overall rates in agriculture/forestry/fishing. Previous research has consistently shown a pronounced increase in the risk of fatal injury with age in the agriculture/forestry/fishing industry [Hanford et al., 1982; Hoskin et al., 1988; Myers, 1989, 1990; Kisner and Pratt, 1997; Fiedler et al., 1998; Hard et al., 1999, 2002; Mitchell et al., 2002; Meyer, 2005]. Previous studies have also suggested that older farmers are more likely to operate older tractors [Gelberg et al., 1999; Voaklander et al., 1999; Sanderson et al., 2006] and are not as likely to use protective devices [Wadud et al., 1998; Pickett et al., 1999; Hwang et al., 2000]. Tractor longevity suggests that older farmers will continue operating older tractors not equipped with rollover protective structures (ROPS) rather than purchasing new equipment [Myers et al., 2009]. Until this older equipment is removed from the workplace or retrofitted with ROPS, the high rates in the agriculture/forestry/fishing industry will likely remain unchanged.

In this study, we also found that self-employed workers had higher rates of machine-related incidents than all other workers. Coupled with the high fatality rates found in the agriculture/forestry/fishing sector, these results reaffirm findings of previous researchers that reported an increased risk to self-employed workers in agriculture/forestry/fishing [Mirabelli et al., 2003; Bunn et al., 2006]. Self-employed workers are disproportionately employed in the high-risk industries of agriculture and construction [Personick and Windau, 1995]. While there are many advantages of self-employment, self-employed workers may have less stable income [Mirabelli et al., 2003] and may be exposed to work hazards for longer hours [Personick and Windau, 1995]. Self-employed workers may also have less stringent safety and health practices [Mirabelli et al., 2003] and are not covered by OSHA regulations and standards (Public Law 91–596). When considering the toll of machines on work-related fatal injuries and focusing prevention efforts, the disproportionate share of fatal injuries among the self-employed deserves continued attention.

The decrease in the overall rate of machine-related deaths was 41%. While mobile machinery accounted for a larger number of deaths during the time period, the decrease in fatality rates (34%) for mobile machinery was lower than the decrease in stationary machine-related rates (64%). This substantial decrease in the rates for stationary machine-related deaths may be due to a shifting workforce from the manufacturing of goods to the provision of services [Loomis et al., 2004; Lee and Mather, 2008; Morse et al., 2009], but may also be due to engineering modifications that make stationary machines safer (e.g., new machine designs and new protective technology) [Herbert and Landrigan, 2000; Stout and Linn, 2002]. The less substantial decrease in the rates for mobile machine-related fatalities may be due to the work environment. Industries such as agriculture/forestry/fishing, construction, and mining utilize a higher proportion of mobile machines compared to stationary machines. The safety performance of mobile machines in these work settings is more difficult to control than in assembly-line environments that may be more typical of stationary machines [Baker et al., 1992; Ringen et al., 1995]. As argued by Baker et al. [1992], "despite improvements in machinery…further design changes are needed to provide automatic protection."

Preventing Machine-Related Fatal Injuries

Each type of machine can present its own dangers. Injury prevention strategies are often applied at work settings. Accordingly, implementing prevention measures requires an understanding of the distribution of machine-related fatalities by work setting. Knowing the distribution of machine-related deaths across industry coupled with understanding the relative contribution of specific events leading to those deaths provides a foundation for effectively focusing and prioritizing injury prevention efforts. These results confirm the role of tractors, forklifts, earthmoving machines (e.g., excavators, graders, and loaders), and cranes in occupational fatalities. Prevention strategies for each of these machine types are discussed below.

Tractors have a high center of gravity and are often operated on sloping, uneven terrain, making them prone to overturns [FSA, 2000; Springfeldt, 1996]. Though ROPS, combined with seat belt use, are attributed with effectively reducing tractor-related fatal injury rates in Nordic countries [Thelin, 1990; Springfeldt, 1996; Springfeldt et al., 1998; Thelin, 1998], multiple studies have suggested why the same has yet to occur in this country. Authors from those studies have pointed to a lack of consistent ROPS use due to regulatory exclusions [Karlson and Noren, 1979; Reynolds and Groves, 2000; Wilkins et al., 2003] combined with tractor longevity [Kelsey et al., 1996b; Springfeldt, 1996; Reynolds and Groves, 2000; Wilkins et al., 2003], ROPS retrofitting challenges [Kelsey and Jenkins, 1991; Springfeldt, 1996; Kelsey et al., 1996a; Kelsey et al., 1996b; Reynolds and Groves, 2000; Wilkins et al., 2003; Jenkins et al., 2012], and ROPS removal by farmers [Kelsey et al., 1994].

Further, the Nordic success in preventing tractor roll over fatalities is attributed to the impact of an engineering design with effective legislation affecting tractor manufacturers and retail dealers, rather than relying on educational approaches to "inform tractor owners of the value of ROPS" [Springfeldt et al., 1998]. The situation in the United States is somewhat different. In 1985, the American Society of Agricultural Engineers adopted a voluntary standard that encouraged installation of ROPS and seat belts on all new tractors. Even though all major manufacturers agreed to adopt this standard a year later [Loringer and Myers, 2008] and ROPS prevalence has increased since the early 1990s, there are many farms still using tractors without ROPS [Loringer and Myers, 2008]. Though there is evidence that ROPS prevalence is approaching the level required to begin significantly reducing fatal injury rates [Myers and Hendricks, 2010], the United States is still at least a decade from seeing fatality rate reductions of the magnitude seen in Northern Europe [Loringer and Myers, 2008].

Forklifts are highly maneuverable, narrow machines that can overturn when operated at high speeds, driven around tight turns, and over uneven surfaces, or when elevated loads become unbalanced [Janicak and Deal, 1999; Collins et al., 1999a; Lifschultz and Donoghue, 1994; Horberry et al., 2004]. Forklifts pose additional hazards for pedestrian workers [Born et al., 1996; Stout-Wiegand, 1987], particularly in manufacturing, freight handling, and warehousing settings with narrow aisles where pedestrian workers and forklifts share travel space [Collins et al., 1999a; Horberry et al., 2004; Larsson and Rechnitzer, 1994]. Historically, forklift injury prevention interventions have focused on occupant protection and operator training [Cohen and Jensen, 1984; Janicak and Deal, 1999; Horberry et al., 2004], and less attention has been paid to proper facility design [Booth, 1979; Larsson and Rechnitzer, 1994; Collins et al., 1999a, 1999b]. The application of traffic engineering principles (e.g., attaining separation of pedestrian workers from forklift movements in space and/or time) and technology (e.g., installation of load-sensing speed limiters) demonstrated at manufacturing sites in Australia [Horberry et al., 2004] offers promise for improving forklift safety. Horberry [2011] provides a framework for designing traffic management systems that eliminate, or at least minimize, forklift/pedestrian worker conflicts.

Earthmoving machinery is often operated on sloped terrain, is transported on flatbed trucks, and trailers, and often has limited operator visibility that places pedestrian workers at risk of being run over [Baker et al., 1992; McCann, 2006; Hinze and Teizer, 2011]. Fatal injury ratios derived from Mine Safety and Health Administration data suggest that pedestrian workers around earthmoving machinery are at greater risk of fatal injury than the operators themselves [Stanevich, 1986]. The risk to workers on foot posed by earthmoving machinery has been previously noted for the highway and street construction industry [Pratt et al., 2001], the mining industry [Stanevich, 1986], and the excavation industry [McCann, 2006]. Prevention strategies are similar to those already discussed: using ROPS/seat belt combinations [McCann, 2006], coordinating the flow of construction equipment on site [Pratt et al., 2001; Hinze and Teizer, 2011], establishing restricted access zones [McCann, 2006], using spotters [McCann, 2006; Hinze and Teizer, 2011], and developing proximity warning systems [McCann, 2006].

Cranes and their loads can contact energized overhead power lines and create hazards to workers below suspended loads [Janicak, 1997; Shepherd et al., 2000]. From a study of OSHA investigation reports, Beavers et al. [2006] note that "most workers who die from crane-related events are not crane operators; rather they are specialty trade workers … who may not automatically be included in training programs related to crane safety." Their contention is supported by others [Häkkinen, 1993; Paques, 1993; Suruda, 1988; Shepherd et al., 2000; Neitzel et al., 2001; Chi et al., 2009]. As with forklifts, prevention efforts have historically focused on operator training and safe work practices (e.g., maintaining safe clearances from electrical lines) [Shepherd et al., 2000]. Deaths can be prevented by either avoiding the power line contact, or preventing electrical energy transfer to the crane boom, load line, or load in the event of inadvertent power line contact. Prevention methods include de-energizing or removing power lines, insulating power lines and boom tips, installing insulating links on crane lines, and using proximity warning detection [Suruda, 1988; Shepherd et al., 2000; Neitzel et al., 2001; Homce et al., 2001; Chi et al., 2009]. To support prevention measures mentioned above, some authors suggest the following administrative controls: developing site safety and crane safety plans, assigning a competent person to manage crane lifting operations, and the certifying crane operators and riggers [Beavers et al., 2006].

Strengths and Limitations

Our study findings are based on a census of all fatal work-related deaths in the U.S. identified from multiple source records. Dating back to 1992, these data have been collected using a standard methodology for sufficient time to enable assessment of trends. However, for a variety of reasons, such trend analyses need to be viewed in the context of certain limitations. While the basic methodology and structure of the CFOI data have remained constant, several primary coding systems used to classify the data have changed substantially over the past two decades. For some code systems, we adjusted the case definition for our study to reduce the impact of differences (e.g., including selected vehicles, such as tractors, with machines). For other code schemes (e.g., industry), we constrained analyses to those years containing data that were coded based on a single coding system. While information on detailed subindustries and OIICS event and exposure is available from the CFOI data, analyses by these details were constrained by the number of fatalities relative to the number of categories for a given variable. The decision to focus on trends over time further constrained depth of analyses. Targeting prevention measures would benefit from identifying those industry, machine, and event combinations with the highest annual fatality rates. However, in most instances the number of annual cases in the industry, machine, and event combinations do not support such detailed analyses.

Other limitations are related to the fatality rates that are presented in this study. First, calculating annual fatality rates requires the use of different data systems which create inconsistencies, compromises, and assumptions. For example, CFOI includes fatalities to volunteers; however, volunteers are not included in the CPS denominator. Second, an ideal exposure measure for calculating rates does not exist, so population-based employment data are used as a surrogate for exposure. While we may know the number of workers in a given category (e.g., age group or industry sector), we do not have information on the number of hours those workers are actually exposed to a given machine, or even the total number of workers in that category who are exposed to machinery. The assumption is that a greater number of deaths per full-time equivalent represents a greater risk, though we must acknowledge that it might really mean a lower risk, but greater exposure to machinery. A final but related issue is the fact that the rates presented in this study were not adjusted for age. We recognize the importance of making age adjustments to correct for crude differences for an outcome resulting from different age distributions, particularly when the outcome is related to an increased probability of occurrence such as an increased risk of cancer among older age groups. However, making age adjustments for machinery incidents requires some type of exposure or prevalence estimates of machine operation by age. Given that this type of exposure data is not available, the crude rates presented in this study are likely the most beneficial measure of risk.

CONCLUSIONS

Results presented in this study confirm that the number of occupational fatalities due to machines declined from 1992 through 2010. However, this study reaffirms that the same worker groups (working with the same machines in the same types of events) are still at highest risk of being fatally injured. The most hazardous machines by industry continue to be tractors in the agriculture/forestry/fishing sector; excavation machines in the construction industry; and forklifts in multiple industries. These findings present ongoing challenges to safety professionals and others responsible for developing and implementing injury prevention strategies. The disproportionate share of machine-related fatalities among the self-employed suggests a need to improve the distribution of workplace safety and health information and injury prevention methods to these workers. The slower rate of decline of incidents involving mobile machinery validates the need to intensify efforts to minimize dangers posed by tractors, excavators, forklifts, and other mobile machines. While stationary machines have a long history of “engineering out” hazards, mobile machine safety may still be too dependent on educating workers to “work safely” on and around equipment.

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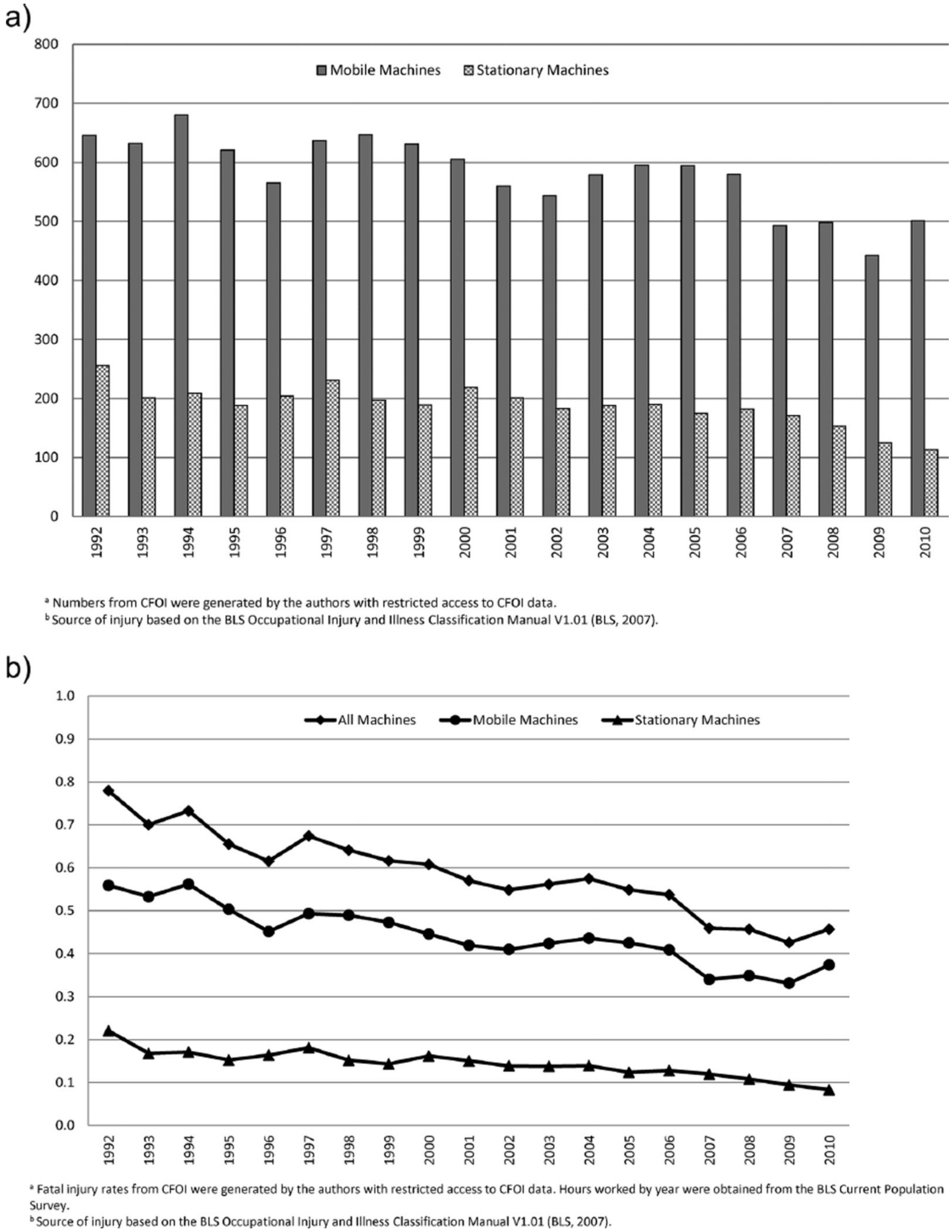
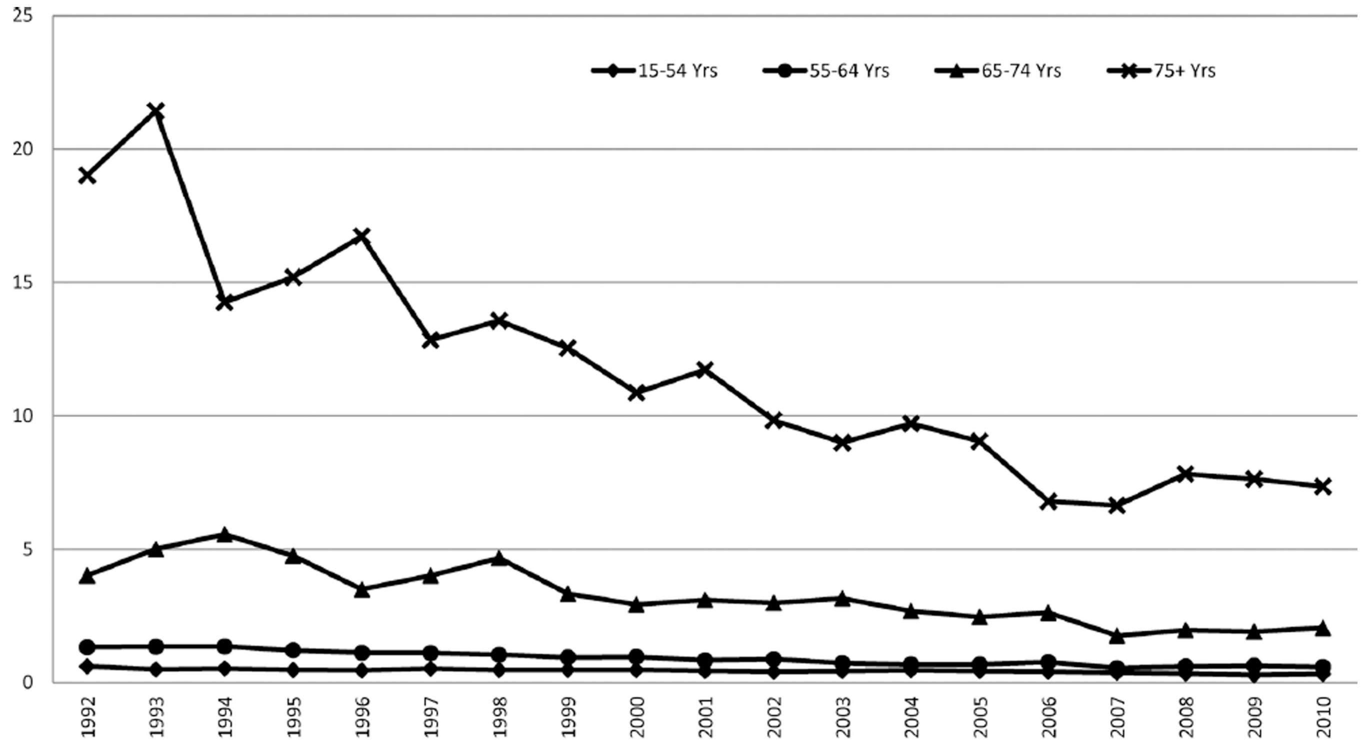


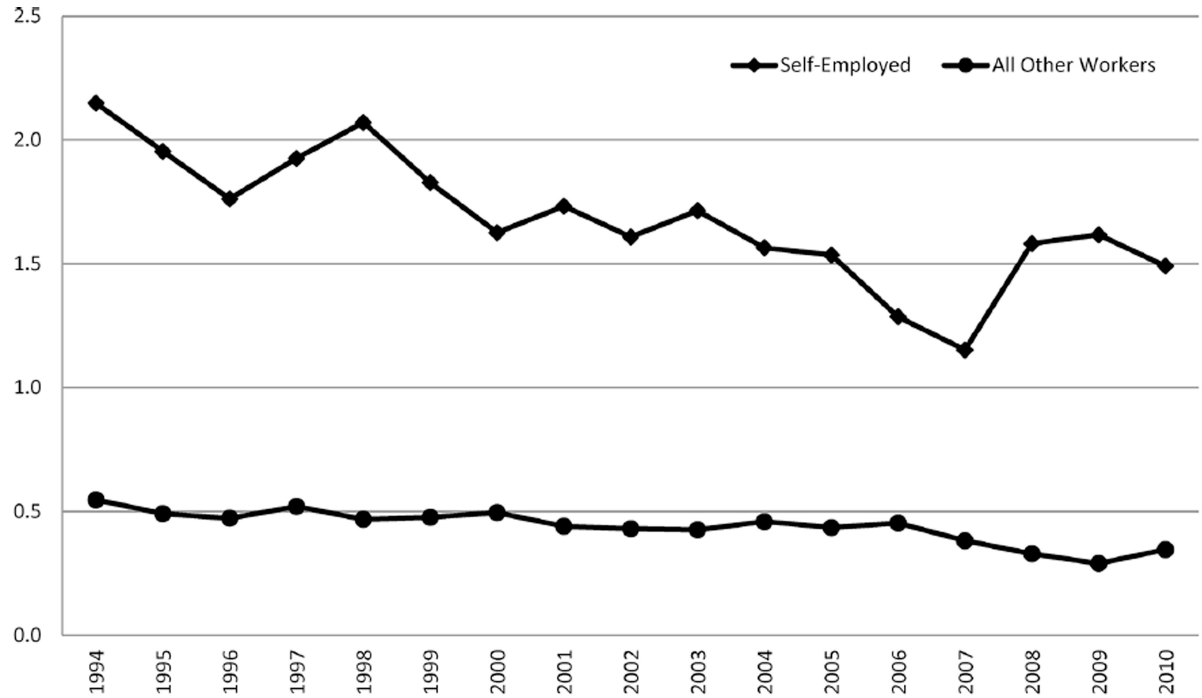
FIGURE 1.

a) Number[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) by year and machine type, 1992–2010. **b**) Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) by year and machine type, 1992–2010.



[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year and age group were obtained from the BLS Current Population Survey.
[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).

FIGURE 2.
Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) by year and age group, 1992-2010.



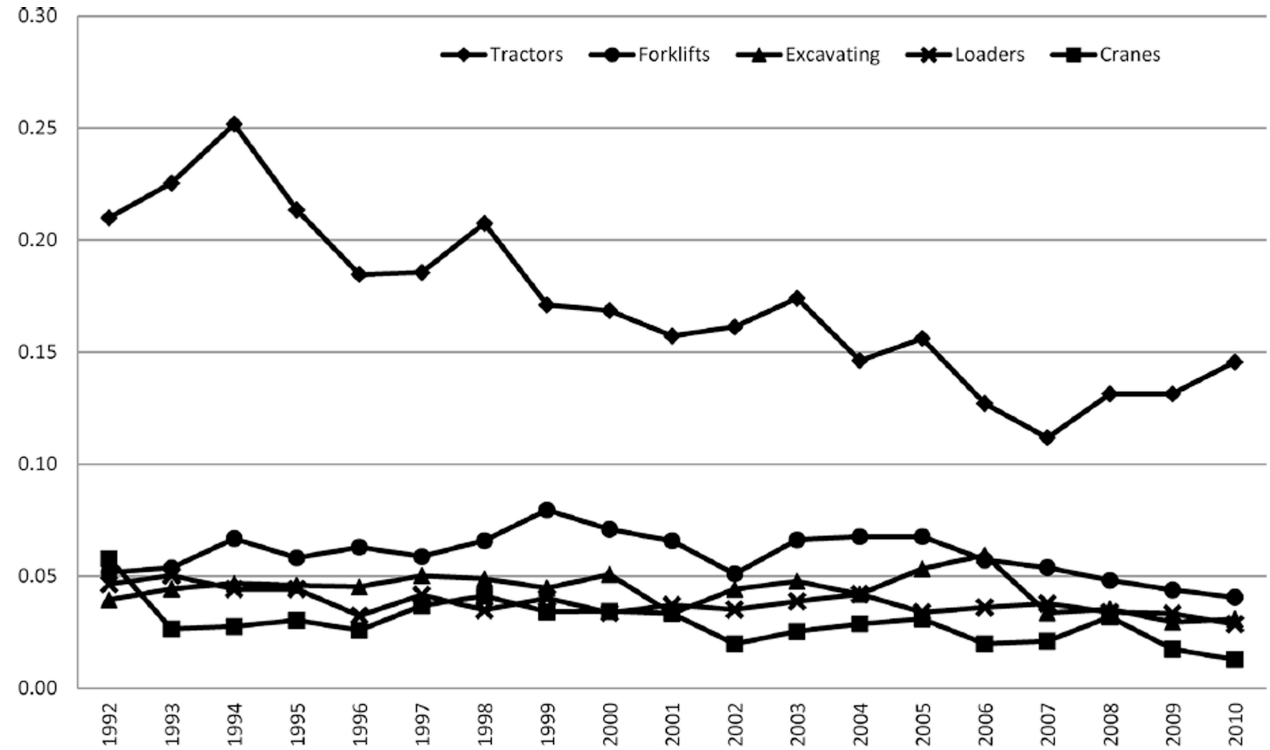
[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year and worker type were obtained from the BLS Current Population Survey.

[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).

[c] Number of hours worked not available for self-employed workers for 1992 through 1993. Number of hours worked for both self-employed and all other represent primary job only.

FIGURE 3.

Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) by year and worker type, 1994-2010[c].

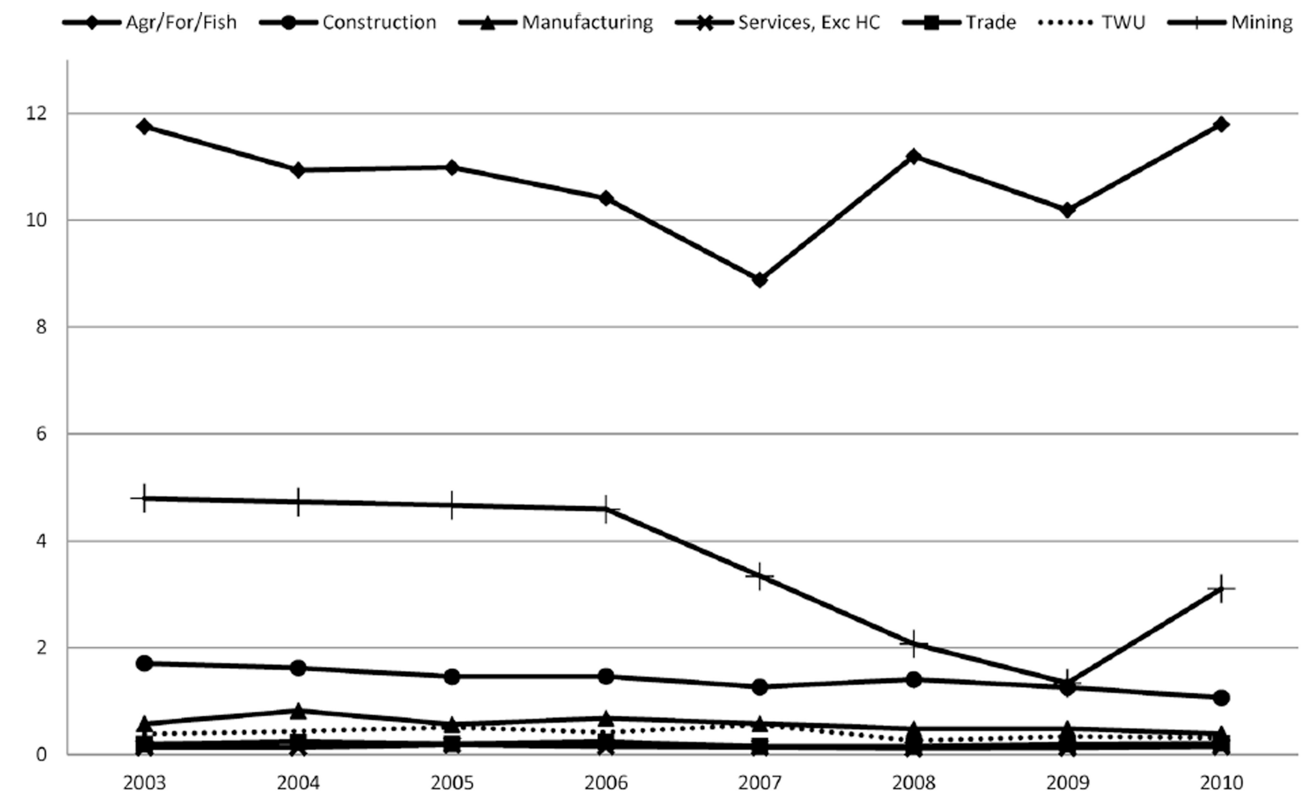


[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year were obtained from the BLS Current Population Survey.

[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).

FIGURE 4.

Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) by year and machine type, 1992-2010.



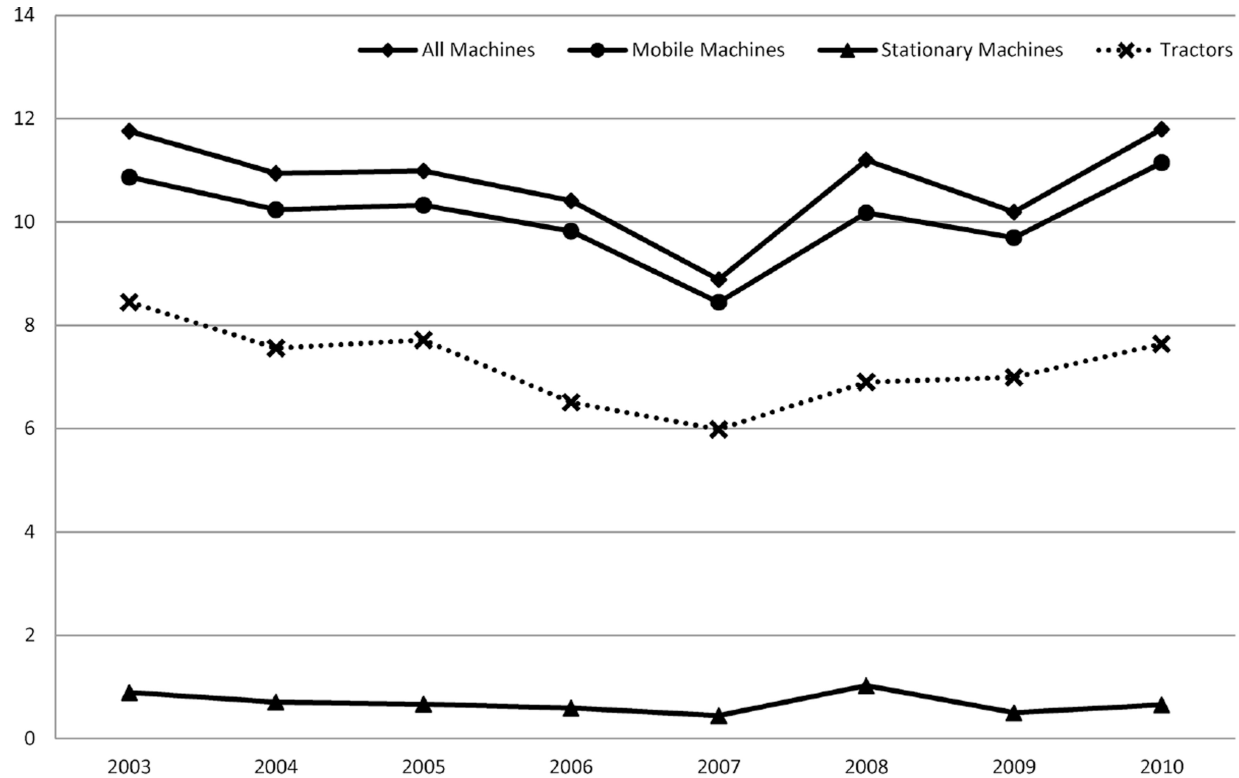
[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year and industry were obtained from the BLS Current Population Survey.

[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).

[c] Industry based on the North American Industrial Classification System (OMB, 2002).

FIGURE 5.

Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) by year and industry[c], 2003–2010.



[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year for the agriculture/forestry/fishing industry were obtained from the BLS Current Population Survey.

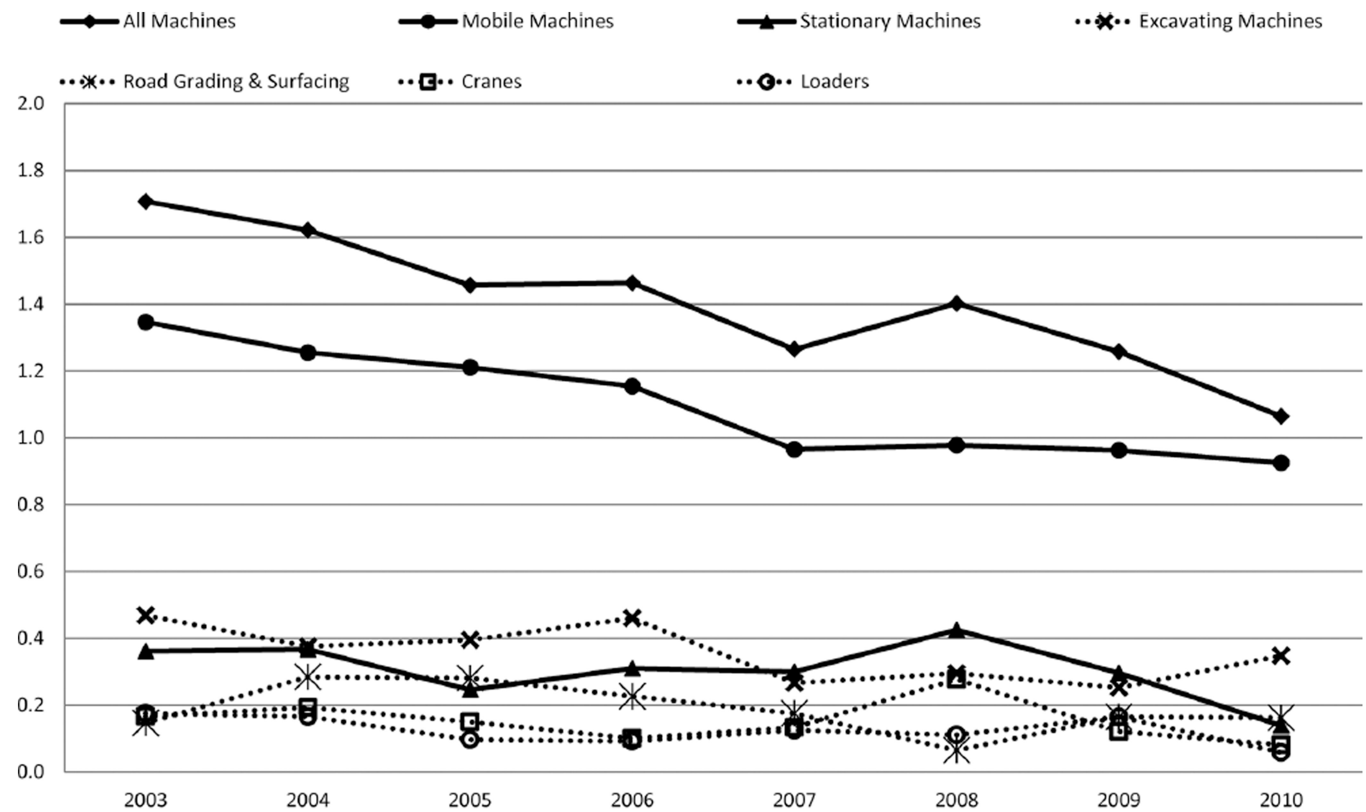
[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).

[c] Industry based on the North American Industrial Classification System (OMB, 2002).

[d] Machine type categories are not mutually exclusive. The category for mobile machines includes tractors.

FIGURE 6.

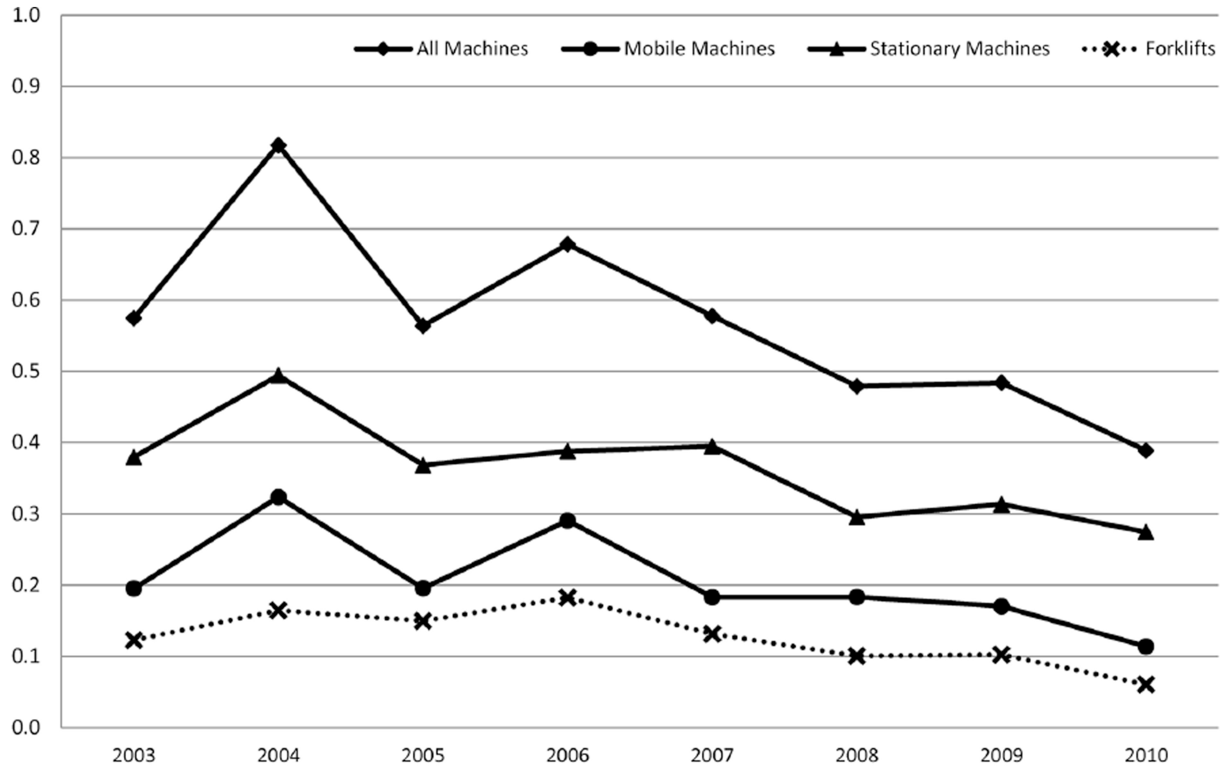
Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) in agriculture/forestry/fishing[c] by year and machine type[d], 2003–2010.



[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year for the construction industry were obtained from the BLS Current Population Survey.
[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).
[c] Industry based on the North American Industrial Classification System (OMB, 2002).
[d] Machine type categories are not mutually exclusive. The category for mobile machines includes excavating machines, road grading and surfacing machines, cranes, and loaders.

FIGURE 7.

Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE), in construction[c] by year and machine type[d] 2003–2010.



[a] Fatal injury rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by year for the manufacturing industry were obtained from the BLS Current Population Survey.
[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 (BLS, 2007).
[c] Industry based on the North American Industrial Classification System (OMB, 2002).
[d] Machine type categories are not mutually exclusive. The category for mobile machines includes forklifts.

FIGURE 8.

Rate[a] of occupational machine-related[b] fatalities per 100,000 full time equivalent (FTE) in manufacturing[c] by year and machine type[d] 2003–2010.

TABLE I

Occupational Injury and Illness Classification System (OIICS) Source of Injury Codes[a] Selected for Analysis by Machine Type

Mobile machines	Stationary machines
Agriculture and garden machinery (source code = "31")	Agriculture and garden machinery, not elsewhere classified (source code = "319")
Construction, logging, and mining machinery ("32")	Mineral sorters, separators, and concentrators ("3242")
Mobile cranes ("3434")	Heating, cooling, and cleaning machinery and appliances ("33")
Bucket, or basket hoist–truck mounted ("3461")	Material handling machinery except mobile cranes ("34")
Forklifts and tractors ("85")	Metal woodworking, and special material machinery ("35")
	Office and business machinery ("36")
	Special process machinery ("37")
	Miscellaneous machinery ("39")

[a]Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 [BLS, 2007].

TABLE II

Number[a] and Average Annual Rate[a] of Occupational Machine-Related[b] Fatalities by Industry and Machine Type, 2003-2010

	Total			Mobile machinery			Stationary machinery		
Industry	**No. deaths**	**Percent (%)**	**Rate per 100,000 FTE**	**No. deaths**	**Percent[c] (%)**	**Rate per 100,000 FTE**	**No. deaths**	**Percent[c]**	**Rate per 100,000 FTE**
Ag/for/fish	2,063	37	10.8	1,929	45	10.1	134	10	0.7
Construction	1,204	22	1.4	941	22	1.1	263	20	0.3
Manufacturing	776	14	0.6	282	7	0.2	494	38	0.4
Services, Exc HC	725	13	0.1	564	13	0.1	161	12	0.03
Trade	319	6	0.2	225	5	0.1	94	7	0.1
Trans/wrhse/util	247	4	0.4	178	4	0.3	69	5	0.1
Mining	226	4	3.5	153	4	2.3	73	6	1.1
All others	19	<1	–	10	<1	–	9	<1	–
Total	5,579	100	0.5	4,282	100	0.4	1,297	100	0.1

[a] Numbers and rates from CFOI were generated by the authors with restricted access to CFOI data. Hours worked by industry were obtained from the BLS Current Population Survey.

[b] Source of injury based on the BLS Occupational Injury and Illness Classification Manual V1.01 [BLS, 2007].

[c] May not add to 100 due to rounding.