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An Aging Workforce and Injury in the Construction Industry

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The relatively large birth cohort between 1946 and 1964, combined with the economic recession in the first decade of the 21st century, have led to an increase in the proportion of older workers in the US workplace. Understanding the health and safety needs of an aging workforce will be critical, especially in the construction industry, where physical job demands are high. This paper reviews the epidemiologic literature on the impact of age on injury among workers in the construction industry in terms of cause, type, and cost. PubMed was searched by using the following terms: older workers, construction, construction industry, injury, and age. The available studies reported that, among the construction industry workforce, older age at injury was related to higher injury costs but not to number of injuries. The higher injury costs associated with worker age are likely due in part to the severity of the injuries sustained by older workers. Identification of injury trends and subsequent analytical research efforts designed to ascertain factors associated with injury among older construction workers are needed for employers to effectively manage a health and safety program that addresses the needs of the aging worker.

accident prevention; aging; facility design and construction; work; workers' compensation; wounds and injuries

INTRODUCTION

The relatively large birth cohort between 1946 and 1964, combined with the recent economic recession during the first decade of the 21st century, have led to an increase in the proportion of older workers in the US workplace. For example, a reversal of the 20th century trend toward earlier retirement has been observed as a growing number of employees are planning for longer working careers (1, 2). As workers continue to delay retirement, understanding the health and safety needs of an older-aged workforce will become increasingly important in the near future.

Why is there a need to address injuries among older workers in the construction industry? First, construction is a physically demanding industry (3). Second, construction workers' injuries and illnesses are among the most costly across all industries (4). Third, compared with white-collar workers, construction workers experience increasing chronic health conditions over time (5). Lastly, compared with younger workers, workers from about age 50 years have been considered at increased risk of injury. This hypothesis was based on the notion that reduced physical capabilities associated with older age in areas such as strength, balance, and processing speed would increase risk of injury (6). In fact, this is not the case. Analyses of workers' compensation claims data indicate that older workers typically have a lower frequency of workplace injuries but higher injury-related costs than younger workers do (1).

The goal of this review is to summarize the published epidemiologic literature that examined the causes and types of injuries and their related costs with respect to age for the construction industry. Evaluating injury trends among older workers in the construction industry is a strategic goal for the following agencies: the National Institute of Occupational Safety and Health, the National Institute of Occupational Safety and Health National Occupational Research Agenda, and The Center for Construction Research and Training. There is a knowledge gap in the field of occupational injury, especially in terms of characterizing the types and causes of construction injuries among older workers. These data are needed to design targeted interventions aimed at preventing work-related injuries among older construction workers to keep them employed, as well as to reduce injury costs (7, 8).

A PubMed search was conducted that included combinations of the following terms: older workers, construction, construction industry, injury, and age to identify original research articles published from 1998 through June 2011 among US populations. We did not include articles published prior to 1998 because a major shift in the early to mid-1990s included development of a national construction safety and health research agenda that makes studies conducted prior to

that time less representative of the present-day construction industry environment (9). When construction, injury, and age were searched together, 191 papers were identified but only 10 were used (10–16). When the terms construction industry and older workers were searched together, 22 papers were identified and only 8 were used (12, 14, 17, 18). Articles were excluded if they did not pertain to the construction industry or older workers and included at least one of the following topics: injury cause, injury type, or injury cost.

Once the first author (N. V. S.) completed the search, the second author (L. M. B.) conducted the same search to ensure that no relevant papers were missed. We identified an additional 9 relevant articles that were either seminal papers in the field based on the authors' knowledge or were articles included in the reference list of one of the articles identified by the PubMed search (4, 5, 7, 19–22), some of which were studies based outside of the United States (23–28).

AN AGING US WORKFORCE

The proportion of US workers 55 years of age or older will increase as the participation rate of workers 16–24 years of age declines within the next decade. The proportion of US workers 55 years of age or older relative to all workers has increased from 31.3% in 1998 to 39.4% in 2008, and it is estimated to reach 43.5% by 2018 (29). According to analyses of data from the Health and Retirement Study, possible reasons for the increase in retirement age include decreases in Social Security benefits, diminishing value of private pension portfolios, and increasing health and longevity (30).

Prior to the mid-1980s, there were incentives to retire early. Retirement was a planned phase of life in the early 1900s that was encouraged by the government and private sectors. The Social Security Act of 1935 legislated a social insurance program that provided income for retired workers over the age of 65 years. Then, in 1961, the retirement age requirement was lowered to 62 years. In addition, corporate pension plans designed to supplement Social Security benefits needed to provide income until only about age 70.2 years, the average life expectancy in 1961 (31, 32). As of 2008, the average life expectancy in the United States has reached 78.4 years (33). Overall, the legislative and corporate climate until recently has encouraged retirement as early as 55 years of age (34).

Within the past few decades, a typical retirement age has become less defined. Legislative changes, such as the Age Discrimination in Employment Act of 1986 and the Pension Protection Act of 2006, have enabled workers to delay retirement without penalties. In addition, delaying retirement has in some cases become an economic necessity. Defined contribution retirement plans have become more popular than defined-benefit plans for some, while Social Security may be the only means of retirement for others (35). Thus, workers are encouraged to stay on the job longer to maximize their retirement benefits (29).

An aging workforce in the US construction industry

The US nonprofit Center for Construction Research and Training reported a 70% increase in the number of paid construction workers from 1977 to 2002 (36). The number of jobs in the construction industry is expected to continue to grow by 19% from 2008 to 2018, compared with a projected 11% for all industries combined (37). The growth of the construction industry is expected to be hindered in the future by a shortage of skilled workers (38). Thus, keeping skilled workers employed in the industry for as long as possible is a high priority in the United States (11).

The increasing average age of the construction industry workforce is consistent with the national trend observed for all industries, where the median age of the workforce has steadily increased from 39.4 years in 2000 to 42 years in 2010. In the construction industry, the median worker age was 37.9 years in 2000 and 40.4 years in 2010 (39). As described above, increases in the average workforce age may be explained in part by the decreasing rates of younger workers entering the workforce, as well as changes in the financial resources of older workers.

Chronic disease and functional impairment cause serious limitations for construction workers as they age (10, 19). Dong et al. (5) analyzed data from a 10-year follow-up study (1998–2008) of older construction workers and found a persistent disparity in health status between construction and white-collar workers as they age. For example, the risk was higher for older construction workers, compared with white-collar workers, for back problems (odds ratio = 1.54, 95% confidence interval: 1.10, 2.14) and for functional limitations, such as not being able to reach/extend arms up (odds ratio = 2.18, 95% confidence interval: 1.40, 3.39) or to lift/carry 10 or more pounds (1 pound = 0.45 kg) (odds ratio = 1.67, 95% confidence interval: 1.03, 2.72). The disparity Dong et al. (5) reported for musculoskeletal diseases is likely related to the physically demanding tasks required in the construction trades (3, 26).

Susceptibility to injury among an aging workforce

Benjamin et al. (40) contend that older workers may not be able to reduce their work hours or switch to less physically demanding work without risking the loss of or a reduction in their pension and/or health benefits. Thus, older workers may find themselves in a difficult financial situation when deciding whether to remain in the workforce. If they continue working for financial reasons, they may be unable to perform the same tasks as well as or as safely as their younger counterparts.

The aging process involves many physical changes that can make construction work tasks more difficult for older workers. For example, physically demanding work may be difficult because of decreased cardiac output and reduced tolerance to physical activity (41). Older workers are also susceptible to losing muscle mass and to subsequent decreases in strength (42). Bone density decreases with age, resulting in a greater propensity for fractures (43). Older adults are also more susceptible to chronic inflammatory disorders, which are associated with arthritis and other conditions that can limit joint range of motion and function (44, 45). Body composition and weight also tend to change with age in a way that predisposes workers to diabetes, hypertension, and reduced flexibility and mobility (46). Overall, the aging process can involve significant physical changes that challenge a worker's ability to perform physically demanding tasks, such as those in construction, without incurring injury.

Table 1. Studies Evaluating Age and Injuries Among Construction Workers

First Author, Year (Reference No.)	Study Design and Population	Research Objective	Main Findings
Kemmlert, 2001 (27)	Cross-sectional analysis of Swedish Occupational Injury Information System data ($N = 1{,}620$)	Report and discuss major factors contributing to slip, trip, and fall accidents	26% of occupational accidents to workers aged 45 years or older were due to slips, trips, and falls compared with 17% of occupational accidents to workers aged 45 years or younger.
Shishlov, 2011 (18)	Cross-sectional analysis of NEISS-work database of emergency-department-treated injuries ($N = 555{,}700$)	Provide national estimates of nonfatal construction industry injuries resulting from falls	Injury rates were twice as high for workers aged <45 years as for workers aged ≥45 years.
			Workers aged >50 years had approximately equal frequencies of contusions/abrasions, sprains/strains, and fracture injuries, whereas younger workers aged <29 years and aged 30–39 years had more contusions/abrasions and strains/sprains than fractures.
			10% more injured workers aged <29 years were treated and released compared with workers aged >50 years.
Schoenfisch, 2010 (7)	Cross-sectional analysis of NEISS-work database of emergency-department-treated injuries ($N = 3{,}216{,}800$)	Identify injuries/illnesses	Workers aged 20–24 years were injured at a rate of 720 per 100,000 FTE, whereas workers aged >65 years were injured at a rate of 140 per 100,000 FTE.
		Estimate number and rate of injuries treated in emergency departments	Workers aged 20–24 years were treated and released from the emergency department 97% of the time, but workers aged >65 years were released 89% of the time.
Hoonakker, 2010 (26)	Cross-sectional health survey among Dutch construction workers ($N = 174{,}090$)[a]	Compare health and injury characteristics among workers by age group	Workers aged >55 years had fewer injuries (7%) compared with workers aged <20 years (20.1%).
			34% of workers aged >55 years and 11% of workers aged <20 years reported back and neck complaints.
			47% of workers aged >55 years and 13% of workers aged <20 years reported upper extremity complaints.
			44% of workers aged >55 years and 15% of workers aged <20 years reported lower extremity complaints.
			25% of workers aged >55 years and 7% of workers aged <20 years reported that their health problems were work related.
			45% of workers aged >55 years and 60% of workers aged <20 years reported being absent because of injury or illness.
Welch, 2008 (10)	Cross-sectional study of roofers aged 45–59 years ($N = 979$)	Investigate the prevalence of medical and MSD conditions among working roofers and examine its relation with age, physical functioning, and work limitations	54% of workers reported at least 1 MSD condition, and 42% reported at least 1 medical condition. Lower back/sciatica was the most reported type of MSD condition.
			50% of subjects with a reported MSD condition were estimated to be younger than age 45 years when the problem began.
			31% reported missing work because of an MSD condition 2 years prior to interview.
			The most common medical conditions were cancer (55%), heart problems (53%), diabetes (33%), burns (38%), and lower back/sciatica problems (35%).
			Increased age was associated with reduced physical functioning, regardless of MSD or medical condition.

Table continues

Table 1. Continued

First Author, Year (Reference No.)	Study Design and Population	Research Objective	Main Findings
Colantonio, 2009 (24)	Cross-sectional study of concussion/intracranial injury that resulted in days off from work from the Ontario Workplace Safety and Insurance Board database ($N = 218$)	Examine work-related TBI and the associated demographic and injury-related factors	Workers aged 25–34 years experienced the most TBIs (27.5%), and workers aged 55–64 years experienced the fewest TBIs (9.7%). Workers aged 35–64 years experienced TBIs by falls more often, and workers aged 17–34 years experienced TBIs by being struck by/against more often. Compared with all other construction trades, trade helpers/laborers experienced the most TBIs. Trade helpers/laborers aged 17–24 years were especially susceptible to TBIs.
Friedman, 2009 (22)	Cross-sectional study of injuries in the construction industry using the Illinois Workers' Compensation Commission claims database ($N = 19,734$)	Describe characteristics of injured construction workers filing claims	Workers aged 16–24 years incurred a mean cost of $17,558, whereas workers aged 55–64 years incurred a mean cost of $53,125; compensation decreased among workers aged >65 years, for whom mean costs were $31,618. A $520 increase in total cost for every 10-year increase in age was observed.
Suarthana, 2007 (28)	Cross-sectional study of Dutch natural stone and construction workers with potentially high quartz dust exposure ($N = 1,291$)	Develop a simple diagnostic model to estimate the probability of individual workers having pneumoconiosis	Workers aged >40 years had 3.3 times the risk of pneumoconiosis compared with workers aged ≤40 years.
Waehrer, 2007 (4)	Cross-sectional study of fatal and nonfatal injuries in the US construction industry using self-reported data from the BLS survey and the National Census database of fatal occupational injuries	Determine the costs of injuries and illnesses in the construction industry	Workers aged 25–44 years were injured the most frequently and incurred the greatest costs. Frequency and cost of injury declined with age after 44 years except for medical costs. Workers aged ≥65 years incurred a mean of $5,831 and workers aged ≤24 years incurred a mean of $2,903 in medical costs.
LeMasters, 2006 (19)	Cross-sectional analysis of self-reported health data among retired union construction workers and retirees from nonconstruction unions (e.g., Communication Workers of America and American Federation of Teachers) ($N = 780$)	Determine whether retired construction workers have poor self-reported quality of life and higher levels of self-reported physical functioning than those in more sedentary occupations	42% of construction workers reported poor health. Male construction workers were 5 times more likely to report poor health compared with nonconstruction workers. 19% of construction workers reported being in severe pain vs. 3% of nonconstruction workers.
Lipscomb, 2003 (15)	Cross-sectional study of injuries among carpenters using Washington State workers' compensation claims data ($N = 16,215$)	Describe the leading cause of morbidity and mortality due to falls	Compared with workers aged ≥45 years, workers aged <30 years were less likely to fall on the same level (RR = 0.73, 95% CI: 0.58, 0.93). Compared with workers aged ≥45 years, workers aged <30 years were less likely to experience a fall from the same level that resulted in paid lost time (RR = 0.48, 95% CI: 0.32, 0.72). Workers' aged 45–54 years claims because of falls from the same level cost a mean of $21,621, whereas workers aged <30 years incurred a mean cost of $4,638. The mean cost for workers aged >55 years declined to $15,468. Workers aged >55 years incurred a mean cost of $21,071 for a fall from elevation, whereas workers aged <30 years incurred a mean cost of $9,034 for a fall from elevation.

Table continues

Table 1. Continued

First Author, Year (Reference No.)	Study Design and Population	Research Objective	Main Findings
de Zwart, 1999 (25)	Cross-sectional study of self-reported health of Dutch construction workers ($N = 44,486$)	Identify age-related work and health issues that can be included in a questionnaire of older construction workers' health	Compared with younger workers (aged 16–30 years), older workers (aged 45–64 years) experienced more complaints about their neck (PR = 3.44, 95% CI: 2.77, 4.28), upper extremities (PR = 2.56, 95% CI: 2.23, 2.94), back (PR = 1.75, 95% CI: 1.57, 1.96), and lower extremities (PR = 1.73, 95% CI: 1.53, 1.96).
LeMasters, 1998 (20)	Cross-sectional study of self-reported health among union carpenters in Ohio ($N = 522$)	Determine the prevalence and risk factors for work-related MSDs	Age and job duration were strongly correlated. Age was a statistically significant predictor of MSDs of the shoulders, hands, and wrists when age was substituted for job duration in the multivariable model. When job duration was added to the model, the association with age was attenuated and lost statistical significance.
Lowery, 1998 (16)	Cross-sectional study of injury at a Denver International Airport construction site using workers' compensation claims data ($N = 4,634$)	Determine the risk factors for injury	The rate of injury (20.5 per 100 workers) for older workers (aged >60 years) was higher than that for younger workers (aged 15–19 years) (6.6 per 100 workers). The rate of injury resulting in lost work time among older workers (aged >60 years) (3.8 per 100 workers) was higher than that for younger workers (aged 15–19 years) (0.9 per 100 workers).
Dement, 2009 (17)	Prospective cohort study of building trade workers from nuclear weapons facilities followed from 1998 to 2004 ($N = 8,976$)	Investigate mortality among construction and trade workers who work at nuclear weapons facilities and who may be exposed to serious hazards	As a function of length of employment in construction trades, risk of mesothelioma and asbestosis increased. Workers who started work when <30 years of age had an increased risk of mesothelioma (SMR = 6.59) and asbestosis (SMR = 53.35).
Arndt, 2005 (23)	Prospective cohort study of male construction workers given medical examinations at baseline and the subsequent recipients of a disability pension at a 10-year follow-up ($N = 14,474$)	Study the disability risk for construction workers	Workers aged 60–64 years experienced occupational disability at a rate of 8,551 per 100,000 person-years, whereas workers aged 25–39 years experienced a rate of 134 per 100,000 person-years. Compared with other nonconstruction, blue-collar workers, workers aged 55–59 years had a SIR of 2.42 (95% CI: 1.79, 3.21) for incidents that caused disability and a SIR of 1.61 (95% CI: 1.47, 1.75) for MSDs that caused disability. Compared with other nonconstruction, blue-collar workers, workers who had worked for ≥30 years had a SIR of 2.54 (95% CI: 1.93, 3.3) for incidents that caused disability and a SIR of 1.72 (95% CI: 1.59, 1.87) for MSDs that caused disability.

Table continues

Table 1. Continued

First Author, Year (Reference No.)	Study Design and Population	Research Objective	Main Findings
Welch, 2010 (11)	Prospective cohort of roofers in the United States ($N = 979$)	Describe the characteristics of roofers who left the trade within 1 year of a baseline interview and the subset who left because of a health condition	Characteristics of roofers who left the trade because of health reasons follow: Older age (OR = 1.18, 95% CI: 1.09, 1.27) Lower physical functioning (OR = 0.91, 95% CI: 0.88, 0.94) More diagnosed MSD conditions (OR = 7.92, 95% CI: 0.98, 64.29) More diagnosed medical conditions (OR = 6.83, 95% CI: 0.80, 58.09) More MSD and medical conditions combined (OR = 4.63, 95% CI: 0.55, 39.15) More likely to have missed work in the 2 years prior to baseline (OR = 1.97, 95% CI: 0.95, 4.10) Moderate economic impact was most common among younger workers (OR = 0.87, 95% CI: 0.80, 0.95), those with poor physical functioning (OR = 0.93, 95% CI: 0.89, 0.97), those who missed any work (OR = 2.8, 95% CI: 1.15, 6.81), and former roofers who left for health-related reasons (OR = 19.04, 95% CI: 4.96, 73.06).
Dong, 2011 (5)	10-year follow-up study (1998–2008) of male workers ($N = 7,200$) that utilized the Health and Retirement Study	Examine the health status of older construction workers in the United States and how occupation and the aging process affect health in workers' later years	Construction trades vs. white-collar workers at follow-up had increases in the following: Arthritis (OR = 1.93, 95% CI: 1.39, 2.67) Chronic lung disease (OR = 1.93, 95% CI: 1.17, 3.20) Stroke (OR = 1.67, 95% CI: 1.14, 2.44) Back problem (OR = 1.54, 95% CI: 1.10, 2.14) Fair/poor physical health (OR = 1.74, 95% CI: 1.23, 2.46) Fair/poor hearing (OR = 1.74, 95% CI: 1.23, 2.46) Functional limitations of reach/extended arms up (OR = 2.18, 95% CI: 1.40, 2.39) and lift/carry 10 pounds[b] (OR = 1.67, 95% CI: 1.03, 2.72) Health problem that limited work (OR = 2.05, 95% CI: 1.47, 2.87) Injury at work (OR = 3.12, 95% CI: 1.10, 8.87) For construction trades, an increased risk of stroke (OR = 1.69, 95% CI: 1.13, 2.53) compared with other blue-collar workers at the time of follow-up At follow-up, higher rate of full-time work among construction workers than the rate for all workers combined, but switching to nonconstruction industries by many of the construction workers
Jackson, 2002 (14)	Cross-sectional study of North Carolina medical examiner records of construction work-related deaths ($N = 535$)	Describe fatal occupational injuries in the construction industry and identify risk factors	The crude death rate was highest among workers aged 65–74 years and lowest among workers aged 18–24 years: 31.8 and 18.3 per 100,000 person-years, respectively.

Table continues

Table 1. Continued

First Author, Year (Reference No.)	Study Design and Population	Research Objective	Main Findings
Janicak, 2008 (12)	Cross-sectional study of construction electrocution fatalities using the BLS Census of Fatal Occupational Injuries ($N = 492$)	Identify differences in the proportion of fatalities by type of electrocution and identify differences in proportions of fatalities by worker age	Among workers aged >65 years, 56% electrocution fatalities were due to contact with electrical wiring, transformers, or other electrical components, and 22% were due to contact with overhead power lines. More than 50% of deaths among younger workers (aged 16–19, 20–24, 25–34 years) were due to contact with overhead power lines. Significantly greater proportions of deaths from electrocutions were observed among younger workers aged 16–19 years (PMR = 144.72, M-H $X^2 = 4.74$, $P < 0.05$) compared with older workers aged ≥64 years (PMR = 75.69, M-H $X^2 = 45.75$, $P < 0.5$).
Dement, 2005 (21)	Cross-sectional study of US Department of Energy construction workers ($N = 3,510$)	Determine hearing loss among older construction workers exposed to high noise levels	92.7% of workers aged >65 years had hearing loss. Compared with the control group (<80 dBA exposures), Department of Energy workers with >33 years of trade work had a greater odds of materials hearing impairment (OR = 2.2, 95% CI: 1.5, 3.2).

Abbreviations: BLS, Bureau of Labor Statistics; CI, confidence interval; FTE, full-time equivalents; M-H, Mantel-Haenszel; MSD, musculoskeletal disorder; NEISS, National Electronic Injury Surveillance System; OR, odds ratio; PMR, proportionate mortality ratio; PR, prevalence ratio; RR, rate ratio; SIR, standardized incidence ratio; SMR, standardized mortality ratio; TBI, traumatic brain injury.

[a] Estimated study size based on information provided in the publication.

[b] One pound = 4.54 kg.

AGE-RELATED INJURY IN THE CONSTRUCTION INDUSTRY

Because of the nature of the trade, most construction workers experience a physically demanding work environment on a daily basis. The industry is characterized by stressful environmental conditions (e.g., harsh weather) (47), long work hours (48), irregular work periods (49, 50), unpredictable workplaces, and noncontinuous employment (51). The physical demands of the job involve exposure to heavy lifting and materials handling, use of vibrating tools, awkward postures, prolonged static positions, and working while injured or in pain (52). These demands can eventually result in injury, missed work, and disability (19, 53, 54). Additionally, most construction tasks involve a combination of multiple physical exposures, further increasing the probability of injury and disability (3). Therefore, one method to reduce the burden of injury among construction workers is to identify susceptible populations, such as older workers, and characterize their injuries in terms of cause, type, and severity (i.e., cost) to appropriately focus on the best available prevention strategies.

Table 1 shows the most relevant studies related to the cause, type, and/or cost of injuries in the construction industry, with respect to age. In summary, findings from these studies indicate that injuries are less frequent but more severe among older construction workers compared with younger workers, thus requiring older workers to take longer to recover (3, 7, 26). These injury characteristics among older workers translate into higher compensation costs due in part to longer lost work time and disability.

Causes of injuries in the construction industry

Injuries due to falls are a major concern for the construction industry. Falls are the most common cause of fatal injury and are ranked among the top 3 most common causes of nonfatal injuries (e.g., 22, 36, 55). However, the data regarding frequency of fall-related injuries among older workers are inconsistent.

Kemmlert and Lundholm (27) reported that the proportions of slip, trip, and fall incidents were greater among male workers aged 45 years or older compared with workers less than 45 years of age. The study consisted of 1,620 reports of slip, trip, and fall incidents from the Swedish Occupational Injury Information System and included construction work as well as electrical, agricultural, metal machine, building metal, and material handling work (27). Colantonio et al. (24) analyzed workers' compensation data from Ontario, Canada, and found that 76% of the traumatic brain injury claims of construction workers aged 55–64 years were from falls, compared with 45% of claims from workers aged 17–24 years. In contrast, Shishlov et al. (18) reported a 2-fold decrease in the fall-injury rate among workers 55 years of age or older (45/10,000 full-time equivalents) compared with workers less than 20 years of age (114/10,000 full-time equivalents).

The study by Shishlov et al. (18) used data from the National Electronic Injury Surveillance System collected by the National Institute of Occupational Safety and Health to obtain US hospital emergency department data for construction-related injuries ($N = 555,700$). Possible reasons for the inconsistent results among the Kemmlert and Lundholm (27),

Colantonio et al. (24), and Shishlov et al. studies may be due in part to differences in record-keeping practices between the 2 countries, occupations included in the study, or the focus on severe injuries (e.g., those requiring an emergency department visit) in the US study, but not in the Swedish study.

Injuries due to falls are categorized in terms of fall location (e.g., same or different level) and contributing factor (e.g., ladder, scaffold, snow, grease). Falls from elevations have been cited as the most frequent type of fall in the construction industry as a whole. However, among older workers in the carpentry trade, falls from the same level have been found to be most frequent (15). In a study using self-reported data from injured carpentry workers ($N = 4{,}429$), the factors contributing to falls from the same level were found to be tripping over debris, difficult work terrain (e.g., rocky, muddy, uneven), slope of the lot, lack of backfill around the foundation, and difficult access and/or egress from the building (56). Studies involving construction-related falls treated in the emergency department indicated that older workers were more likely to be hospitalized because of falls, indicating a greater severity of injury among older workers (7, 18, 57).

Motor vehicle incidents occur infrequently (22, 58), but they result in some of the most severe injuries to construction workers (7, 59) and are the second leading cause of occupationally related deaths in the construction industry (36). Using the National Traumatic Occupational Fatalities Surveillance System (1980–1992), Ore and Fosbroke (59) found that the motor vehicle incident fatality rate for the construction industry was 2.4 per 100,000 workers across all ages but increased to 6.9 for workers over the age of 65 years. Possible contributing factors in motor vehicle incidents among older workers include age-related degradation in vision, reaction time, cognitive function, muscle strength, and range of motion (60, 61).

The little knowledge we have on older construction workers' motor vehicle incidents is based on national sources of data. Such data cannot account for exposure (i.e., hours of driving); thus, caution should be used when interpreting findings from national data. There is a major gap in our knowledge of motor vehicle incidents among older construction workers, and factors that affect their ability to drive should be considered in developing injury prevention strategies for construction industry workers.

Types of injuries in the construction industry

Musculoskeletal disorders are of particular concern for construction workers. Older workers experience a significant burden of musculoskeletal disorder conditions and continue to work with pain and limitations (10). de Zwart et al. (25) utilized the Dutch Periodic Occupational Health Survey (1983–1993) to determine the prevalence of age-related health issues among older (45–64 years of age) compared with younger (16–30 years of age) construction workers. They found an increased prevalence ratio of complaints related to the upper and lower extremities, back, and neck. Hoonakker and van Duivenbooden (26) utilized the same survey for the years 1989–2003 and found similar results.

LeMasters et al. (20) found that the odds of union carpenters having a musculoskeletal disorder of the shoulders, hands/wrists, and knees were greatest for workers employed for more than 20 years in the industry. Age did not remain a significant predictor in the final multivariate logistic regression model when job duration was added to the model. Musculoskeletal disorders among older workers may predispose them to recurring injuries. Lipscomb et al. (62) found that carpenters who experienced a back injury were at an increased risk of a second back injury within 3 years of the initial injury. Musculoskeletal disorders may also put older workers at risk of retiring from the construction trades earlier than anticipated. Welch et al. (11) found that the odds of leaving the roofing trade early were 8 times higher for workers with a musculoskeletal disorder than for workers without such a disorder.

A minimal amount of research has evaluated other types of injuries besides musculoskeletal disorders among older construction workers. Fractures, contusions/abrasions, and sprains/strains are the most common injury among construction workers over 40 years of age, whereas contusions/abrasions and sprains/strains are the most common among workers under 29 years of age (18). Occupational illnesses such as pneumoconiosis (28), mesothelioma, asbestosis (17), and hearing loss (21) are primarily seen among older construction workers, likely due to the well-recognized latency between first exposure and disease onset.

Injury-related costs in the construction industry

Given the precarious and physically challenging work conditions in the construction industry, coupled with the increasing average age of the workforce, it seems inevitable that the cost of occupational injuries among construction workers will also increase. While construction workers represent only 6% of the US workforce, they account for a disproportionate 15% of costs related to injuries and fatalities for all US industries (4). Vulnerable populations, such as older workers, contribute to much of these costs.

In general, workers' compensation claim costs increase with the age of workers (22). For example, Lipscomb et al. (15) found that costs associated with falls in construction were 3 times higher for those over 45 years of age when compared with those under 30 years of age. Data from Lowery et al. (16) indicated that lost work time and related indemnity costs increased with age. Schoenfisch et al. (7) determined that, although injury rates among older construction workers were lower than among younger workers, the injuries to the more senior workers were more likely to cause more serious problems that required longer hospitalization stays, indicating a decreased ability to recover from an injury.

Physical disability among older construction workers is a major concern because of its effect on overall productivity. The ability to fully recover from an injury becomes increasingly difficult with increasing age. Therefore, the proportion of disability is likely to be higher among older compared with younger workers in the construction industry (11, 23). Relative to younger workers, older workers miss more days of work when injured (7, 63).

Previous research has found that older construction workers are more likely than younger construction workers to die from an occupational injury. For example, The Center for Construction Research and Training utilized the Bureau of

Table 2. Injury and Age Studies of Construction Workers by Injury Cause, Type, Body Part Affected, and Cost

Cause of Injury and Type of Injury (Reference No.)	Body Part Affected (Reference No.)	Associated Cost of Injuries (Reference No.)
Falls, slips, and trips (15, 24)		
MSD (18–20, 23, 25, 26)	Back (25, 26)	Increased hospitalization days (7, 18)
Fractures (18)	Neck (26)	Retirement (11)
Pneumoconiosis (28)	Upper extremities (26)	Lost work days (16)
Mesothelioma (17)	Lower extremities (19, 26)	Disability (23)
Asbestosis (17)		Increased monetary costs (4, 15)
Contusion/abrasion (18)		Functional limitations (5, 19)
Hearing loss (21)		Death (14, 36)

Abbreviation: MSD, musculoskeletal disorder.

Labor Statistics Census of Fatal Occupational Injuries and found that 44% of occupationally related fatalities in 2005 occurred among construction workers over the age of 45 years (36). Jackson and Loomis (14) utilized the North Carolina medical examiner's database of occupational fatalities for the construction industry and found that the crude death rate was highest among workers aged 65–74 years and lowest among workers aged 18–24 years, with rates of 31.8 and 18.3 per 100,000 person-years, respectively.

There may be differences in the cause of death among different-aged construction workers. Janicak (12), for example, found that construction workers aged 16–19 years (proportionate mortality ratio = 144.72, Mantel-Haenszel $\chi^2 = 4.74$, $P < 0.05$) had a greater proportion of electrocution fatalities than expected and that construction workers aged 65 years or older (proportionate mortality ratio = 75.69, Mantel-Haenszel $\chi^2 = 45.75$, $P < 0.05$) had a lower than expected proportion of electrocution fatalities.

Promotion of work ability

The promotion of work ability can enable older construction workers to remain employed and injury free. The Finnish Work Ability Index was developed to assess how long workers are able to work and whether job demands and job content affect their ability to continue work (64). Previous research has used the Work Ability Index to predict sickness absence (65) and disability among older workers (66) in the construction industry. A work ability promotion program was developed and modeled around 4 different actions: 1) adjustments to the physical environment, 2) adjustments to the psychosocial environment, 3) health and lifestyle promotion, and 4) updating of professional skills (67). Tuomi et al. (68) utilized data from a 16-year follow-up study of Finnish municipal workers and found that the model of work ability was strongly associated with the Work Ability Index. In addition, a high Work Ability Index score was associated with high-quality work, high productivity, the ability to function well, and the ability to stay in good health upon retirement (69).

The work ability promotion program has not been studied within the construction industry specifically, but the model could be a useful guide for future interventions. Welch (69) reviewed literature pertaining to the Work Ability Index and construction work and recommended rehabilitation programs for injured workers, ergonomic programs to prevent musculoskeletal disorders, and comprehensive health promotion programs. With regard to ergonomic programs developed to reduce the risk of injury, contractors could integrate knowledge about workstation and task adaptations appropriate for older workers into their commonly held pretask planning meetings on the construction site. Disseminating information that older workers may need to work at lower elevations, need more breaks during heavy physical work, or need more time to complete a task may enhance safety at the job site. Employers may consider providing lighter materials to handle or manual material handling equipment and eliminate long or heavy reaches from ladders (3).

Providing reasonable accommodations for all older workers may be difficult to achieve in physically demanding industries such as construction. Thus, older construction workers may be placed in a difficult position of having to weigh the costs and benefits of continuing to work in such a physically demanding profession. Doing so may result in a feeling of ''job lock'' or the inability to leave a job because of financial or benefits need, or in working while ill (e.g., presenteeism) (40) if retirement is not financially feasible. Improving construction work ability for all ages and physical limitations will require a concerted effort from workers, contractors, unions, owners, policy makers, regulators, and the occupational health and safety community to implement effective programs that can adapt to the unique challenges facing the construction industry (64, 69).

RECOMMENDATIONS FOR FUTURE RESEARCH

Although older workers may experience physical limitations, their ability to add value to an organization is a notable strength. A recent meta-analysis examined the relation between age and several job performance measures. A worker's age was not found to be related to core task performance or level of creativity, but it was related to increased safety performance and decreased counterproductive work behavior (70). Employers who resist adapting work to older workers are susceptible to losing valuable workers and paying more in hiring and training costs (71). Given the dominant role that

older workers will play in the future, it is critical to understand how to shape work environments to take advantage of their talents and to minimize the risk of injury they face on the job (70). For example, researchers have suggested using ergonomic principles to fit the job to the worker (3), wellness programs to keep older workers physically fit (72), and good housekeeping (27).

Despite increased awareness and epidemiologic research related to construction worker health and safety over the last 20 years, the construction industry remains one of the most dangerous in the United States (3). Injury trends among vulnerable workers, such as the growing number of older workers, need to be studied in greater depth to determine specific interventions aimed at preventing age-related injuries and helping older workers remain employed (7, 8). The depth of data available on injury trends among older workers is limited (Table 1). The available literature has focused primarily on injuries due to falls and injuries that result in musculoskeletal disorders, but the characteristics of other types of causes and types of injuries have not been reported in as much detail for older construction workers (Table 2). It is important to note that publication bias may contribute to the paucity of publications in this area. However, the larger issue is that too few studies have been conducted that focus on older workers in the construction industry.

In addition to older workers, Hispanic construction workers, compared with non-Hispanic construction workers, are another vulnerable population that has been found to be at increased risk of injury (73) and death (74, 75). Hispanic construction workers are generally younger than non-Hispanic workers (36), but, when older Hispanic workers are injured on the job, they are more likely to die from the injury. For example, research using the Bureau of Labor Statistics Census of Fatal Occupational Injuries (1992–2000) has found that the fatality risk index among older (aged $\geq$65 years) Hispanic construction workers was greater than among older non-Hispanic workers: 5.5 versus 2.7 (74). Although the topic of injury among Hispanic construction workers was beyond the scope of the present review, it is clearly a topic in need of further research.

Future research should utilize a combination of leading and lagging safety and health performance metrics to determine the relations among safety, injury, and age in the construction industry. Safety and health performance metrics can be used to monitor the level of safety or to motivate those in a position of power to take necessary actions to improve safety. These metrics can also be used to determine how to take action (76). Leading indicators of safety (i.e., actions, events, and processes that prevent the incident from occurring) should be tracked with such metrics as using personal protective equipment, reporting unsafe conditions/actions, or participating in health and safety meetings. Lagging indicators (i.e., reactive measures of safety) can also be utilized by tracking existing occupational injury data (e.g., workers compensation claims, Bureau of Labor Statistics' Survey of Occupational Injuries and Illnesses, or National Electronic Injury Surveillance System-Work). By tracking a combination of leading and lagging indicators, the relation among age, safety, and injury can be determined and the appropriate interventions can be developed.

Crawford et al.'s (77) review of the health and safety needs of older workers found that no intervention studies specifically evaluated strategies to reduce injuries among older workers. Identification of specific injury trends and subsequent analytical research efforts designed to identify risk and protective factors among older construction workers can provide the necessary guidance needed to develop appropriate interventions aimed at maintaining their employment. The American College of Occupational and Environmental Medicine states that it is imperative that more attention and resources be devoted to protecting the employability of older workers to mitigate the impending consequences of the health care crisis brought on by chronic disease among the baby boomers (78). A recommended priority for researchers is to make a concerted effort to disseminate their research results and translate these results into workable recommendations that have the potential to reduce workplace injury among older workers in the construction industry.

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