A Study of Work-Related Injuries among Older Medicare Enrollees

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Dedication

This thesis is dedicated to my family and friends. I thank you all for your encouragement and support throughout this work. Thank you to my partner, Danielle McFalls, for your patience and support during my education. I also dedicate this work to our children Amelia, Porter, and Clara, who I hope will grow up in a safer world.

I also dedicate this thesis to the memory of Dr. Susan Gerberich. I thank you for sharing your excitement for injury prevention. I am grateful for how you inspired and encouraged me while working on this dissertation and throughout my time in the OIP program.

Abstract

Background: Older adults in the US are more often working past the age of 65, typically for financial reasons that prevent retirement. Many older adults still work full-time or physically demanding jobs that could compromise their health and safety. Detecting work-related injuries is challenging in this population, as injuries are less often covered by workers' compensation, a frequent source of surveillance data. This also has implications for the healthcare costs of older workers for whom workers' compensation coverage is inadequate or unavailable.

Objective: The overall objective of this research is to further understand the burden of work-related injuries and healthcare costs to older adults, particularly those enrolled in Medicare, as well as understand how retirement barriers contribute to their risk of work-related injuries. Results may help to inform occupational injury research and surveillance methods, further understand the shifting healthcare costs of work-related injuries, and inform work practices to promote safety during the retirement transition.

Manuscript 1: Aim: Measure the incidence and characterize the burden of work-related medically treated injuries in the 65 and older Medicare population. Methods: Identifying work-related injuries from 2016-2019 Medicare inpatient and outpatient claims data using payer-related and work-related ICD-10-CM codes to estimate the annual incidence of work-related injuries, describing demographic, injury, and healthcare encounter characteristics. Results: Estimated an average annual incidence of 27.6 work-related injury claims per 100,000 Medicare fee-for-service enrollees aged 65 and older. Overall 19% of injuries were hospitalized, and 72% of outpatient visits were in the emergency department. Falls, transportation, and machinery-related causes each accounted for

approximately 20% of injuries, the next most common cause was being struck by/against an object (5%), followed by other causes (17%), or missing causes (18%).

Manuscript 2: Aim: Estimate the impact of workers' compensation coverage on out-of-pocket healthcare costs following a work-related injury. Methods: Case-only study of work-related injuries from inpatient and outpatient Medicare claims, from 2016-2019. Followed up on work-related injuries to examine 90-day inpatient, outpatient, and skilled nursing facility costs incurred by enrollees. Used difference-in-differences, time series regression, and quantile regression to explore differences in claim costs and Medicare enrollee coinsurance/deductibles, based on workers' compensation (WC) coverage. Results: Of 13039 aged Medicare enrollees with a work-related injury, 16% had evidence of workers' compensation coverage from Medicare claims. The WC group averaged $452 (95% CI 395, 509) in excess out-of-pocket healthcare costs for inpatient, outpatient, and skilled nursing care following a work-related injury, compared to these costs in the 90 days before the injury. For those without WC coverage, these costs averaged $603 (95% CI 572, 634). At the 90th percentile of out-of-pocket spending, those without workers' compensation coverage incurred $601 in additional costs over the WC group (95% CI 398, 805).

Manuscript 3: Aim: Estimate the longitudinal effect of job lock on the occupational injury incidence rate among older workers. Methods: Using 2010-2020 data from the Health and Retirement Study, identified two age-based cohorts of workers – those aged 55-64 and age 65 and older. Used repeated measures negative binomial regression models to estimate the longitudinal effect of job lock on occupational injuries. Explored effect modification of work status and self-employment on the effect of job lock. Results: Job lock increased the incidence rate of occupational injuries in the age 55-64 cohort (IRR 1.59, 95% CI 1.25-2.03), but not in the age 65 and older cohort (IRR 0.87, 95% CI 0.54-

1.39). For the age 55-64 cohort, job lock did not have an effect on injuries for those who responded as self-employed or "partly-retired", but these effects were present in full-time (IRR 1.69, 95% CI 1.28-2.25) and part-time workers (IRR 1.89, 95% CI 1.06-3.37), as well as workers who were not self-employed (IRR 1.68, 95% CI 1.29-2.19).

Conclusion: Work-related injuries appear to impact the health of older Medicare enrollees, and Medicare claims data can be a useful data source to study occupational injuries in this population, including healthcare costs. When available, workers' compensation seems to protect Medicare enrollees from incurring some out-of-pocket costs, but this coverage is not common. Since many older adults continue working for financial reasons, this raises concern that these healthcare costs may be financially detrimental to workers. Prior to age 65, job lock appears to effect occupational injury risk and can be a useful measure of retirement barriers if stratified on other aspects of the work arrangement. Taken together, the findings of this study provide further points to build on to understand the burden and costs of occupational injuries to older adults in the US, as well as areas of further study to improve both their workforce and retirement outcomes.

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Organization

The organization of this dissertation provides an initial introductory chapter, a literature review, three stand-alone manuscript chapters, and a concluding chapter. Since the individual manuscripts are formatted for peer-reviewed journals, there may be some redundancy in material.

Chapter 1: Introduction

In 2022, over 10.5 million adults in the US were working past the age of 65, a new height in a decades-long trend of increased labor force participation among older adults[1,2]. This could be the result of many societal factors like improvements to health or educational attainment, but most studies find that people delay retirement for financial reasons, including a dependence on employer-provided health insurance[2–4]. This trend is not trivial, as workplace safety becomes a serious concern for older adults. In 2021, there were 8.4 fatal work injuries per 100,000 FTE aged 65 and older, compared to 3.5 per 100,000 FTE in the overall workforce[5].

An injury or illness is considered to be work-related if an event or exposure from work either "caused or contributed to the resulting condition or significantly aggravated a pre-existing injury or illness", according to the Occupational Safety and Health Administration (OSHA)[6]. However, defining and detecting work-related injuries for older adults becomes challenging. Occupational injury and illness surveillance often relies on employer-reporting, such as in surveys from the Bureau of Labor Statistics, which may not adequately cover a population with a variety of different work arrangements[7,8]. If injured from work, older workers are less like to receive workers' compensation coverage, leading to undercounts in workers' compensation databases, a frequent data source for occupational injury surveillance[9–13].

Along with undercounting work-related injuries, the financial impacts of work-related injuries on the aging workforce may be underestimated. Without workers' compensation coverage, healthcare costs for work-related injuries could go to workers' primary health insurance, which is typically Medicare after the age of 65[9,10,14]. Given the financial need to work in this population, the shift in payers for these healthcare costs

could become a concern for workers' finances. After age 65, work-related injuries may be another source of burden to those who are already vulnerable to high Medicare coinsurance and deductibles[15,16].

Lastly, the very reason workers find themselves unable to retire – whether for finances or to maintain other employer-provided benefits such as health insurance – could become a risk factor for their injuries. Older workers experience retirement barriers differently, with some finding themselves embedded in a career through "job lock", while others can manage a phased retirement by switching jobs, taking on less demanding work, or finding some other control over their working life[3,8]. Studies suggest, particularly for older adults, that balancing their health with the demands of work is important to reduce the risk of injury[17,18]. Given the economic constraints that keep many older adults in the workforce, retirement barriers, job lock, or the work arrangement could similarly be factors in workplace safety.

These are just some key areas to expand on in occupational injury research for older adults and are the focus of this dissertation. The first objective will be to explore detection of work-related injuries among older adults, using Medicare administrative claims data. Following this, the costs incurred by Medicare enrollees for their work-related injuries will be explored, including the role of workers' compensation in protecting enrollees from these costs. Lastly, the focus will be on factors that may help or hinder workers find a safe path to retirement, exploring the impacts of job lock and work arrangements on the risk of work-related injuries.

Chapter 2: Literature Review

Organization

This chapter provides an overview of the economics of an aging workforce and the implications for the health of older workers, including the burden of occupational injury. This overview is followed by a summary of the literature and important data gaps for older workers in the US. The organization of the literature review aligns with the aims of this dissertations and covers: 1) identification of work-related injuries among older workers from various administrative databases, 2) healthcare costs of work-related injuries among older adults, and 3) the contribution of job lock and work arrangements to older adults' risk for work-related injuries.

OVERVIEW OF THE PROBLEM

Economics and an aging US workforce

In the US, a growing aged population has contributed to an aging workforce, which reached 10.5 million workers age 65 and older in 2022[1]. The health and wellbeing of the aging workforce becomes of even greater concern in upcoming years as the labor force participation rate for adults aged 65-74 may reach 32% by 2030[19]. Among a population largely eligible for Medicare, with many nearing the Social Security retirement age, growing employment rates are largely the result of workers delaying retirement for financial reasons[20–22]. Traditional retirement pathways, such as those provided pension plans with set benefits in retirement, have changed to direct contribution plans, incentivizing many older adults to work longer to add to their 401k and savings[2,23]. Less educated older adults, often with more health problems or working physically demanding jobs, tend to face different financial challenges from low

wages or as they find themselves unable to continue working[24]. Health problems can add to the financial challenges of older adults, as 22% of adults aged 65 and older are reported to hold medical debt, with many of them reporting the debt to be from hospitalization (34%) and/or emergency care (31%)[25]. Disparities also exist in job mobility as some older workers find themselves in a "job lock" situation, relying on a full-time employer for health insurance or income, and unable to retire or switch to part time, less demanding work[3,4]. However, research into older adults' work-related healthcare costs, as well as the impact of retirement barriers on health, remains limited.

Occupational injuries and the Medicare aged population

The number of fatal work injuries for workers aged 65 and older has risen with employment trends, increasing by 22% from 2015-2019[26]. The rate of these fatal work injuries has been over twice that of any age group in recent years, at 9.4-10.3 fatal work injuries per 100,000 FTE from 2016-2019, compared with the next highest age group of 55-64 at 4.3-4.7 fatal work injuries per 100,000 FTE[5]. Non-fatal occupational injuries and illnesses also differentially impact older workers, resulting in a median 16 days away from work for workers aged 65 and older in 2019 or twice that of the overall workforce (median 8 days away from work)[27]. Nearly half (48.1%) of the non-fatal cases in 2019 were from falls, slips, and trips[28]. These fatal and non-fatal cases occur as many Medicare-aged workers remaining in physically demanding roles, including service occupations (14.9%) and production, transportation, and material moving (10.8%)[29].

The sections ahead discuss the need to focus aging worker research on 1) improved identification of work-related injuries 2) costs of work-related injuries to society and the worker 3) associations between retirement barriers and work-related health outcomes.

OVERVIEW OF THE STUDIES TO DATE

1. Identification of work-related injuries from administrative databases

Injuries that require medical treatment or result in death will often be captured in hospital records, statewide reporting systems, health insurance claims, or death certificates. Most databases in the US will use the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) coding system to record diagnoses[30]. The ICD-10-CM is developed from ICD-10, which is published by the World Health Organization (WHO) and helps to standardize records of morbidity and mortality all over the world and over time[31]. In the US, the National Center for Health Statistics (NCHS), of the Centers for Disease Control and Prevention, developed the clinical modifications to include greater specificity in coding assignments and expanded injury codes[32]. ICD-10-CM codes include injury diagnoses, as well as external cause of morbidity codes to capture the cause, intent, a patient's status (e.g. civilian, military), the place where the event occurred, or the activities involved[33]. The earlier ICD-9-CM version of coding, which also captures diagnoses and external causes of injury, can be found in some databases, usually prior to October 1, 2015 when HIPAA-covered entities were required to transition to ICD-10-CM[30].

For injury surveillance and injury prevention research, the vast number of ICD-10-CM (or the earlier ICD-9-CM) has necessitated a framework to develop meaningful grouping for injuries. Details embedded within the structure of ICD codes have been used to classify injuries by their nature (e.g. fracture, burn) and body region (e.g. head/neck, torso, extremities), and then further placed into a matrix format (e.g. fracture of the hip) such as the Barell Matrix (ICD-9-CM) or Injury Mortality Matrix (ICD-10-

CM)[34]. Similarly, external cause matrices have been developed and used to classify injuries by cause and intent (e.g. unintentional fall)[35].

To identify work-related injuries, researchers often use these widely accepted frameworks to describe injuries, but there are still many challenges in determining whether an injury has a "work-related" component[36,37]. There is no comprehensive data source for work-related injuries, and electronic records may poorly capture injuries that result from work[38–41]. Traditional studies of occupational injury have often used claims from workers' compensation (WC) insurance, which provides medical and wage benefits to employees who are injured from work[42]. However, WC coverage is often underutilized as workers experience barriers to coverage, and WC is likely to underestimate the burden of work-related injuries[11,13,41–49]. As a result, identifying work-related injuries presents a unique challenge to research and public health surveillance alike, which may use state hospital discharge and emergency department records, workers' compensation payers, other health insurance claims, death certificates, or a combination of sources to identify work-related injuries[11,41,43–45,50,51].

When workers' compensation data are available, studies typically use WC as a highly specific indicator of a work-related injury since workers' compensation insurers have verified injuries as related to the patient's employment. Workers' compensation status can be derived by **linking WC claims** to hospital discharge and ED records, or by using **WC as the expected payer** from other healthcare records. Using WC as a work-related indicator, although specific, is limited because of reporting issues. From multi-source surveillance in Michigan, WC claims were linked to work-related injuries from hospital data and death certificates, showing **wide variation** in the ability of WC claims

to identify work-related crushing injuries (64% identified by WC), skull fractures (56%), burns (21%), and amputations (13%)[43,46–48]. Using WC payers in comparison to work-related ICD-9-CM "e codes" on hospital emergency department records, North Carolina surveillance found only 69% of work-related injuries to be identified by WC[45]. Inpatient hospital data from California, Colorado, and New York showed similar results, with WC as the expected payer for 58-70% of industrial injuries[13]. This limited ability of WC to identify work-related injuries may be due to underutilization of WC, while some workers (e.g. agricultural workers, self-employed) may simply not be eligible for WC coverage[52].

This apparent **underreporting** of work-related injuries to WC has led studies to systematically identify work-related indicators from **ICD-9-CM or ICD-10-CM external cause codes**, typically from hospital discharge or emergency department records, finding codes by place, activity, or cause that are likely to be work-related. Two recent studies have tasked **multiple reviewers** to examine the full list of ICD-10-CM external cause of morbidity codes, flagging potential codes and resolving discrepancies to develop a final work-related code list [41,50]. Bush et al applied this process to identify work-related emergency department visits in Kentucky[41]. When compared to WC payers, the ICD crosswalk identified 36% more work-related ED visits than WC payer alone[41]. Scott et al undertook a similar process to develop a crosswalk for "true" and "suspected" agricultural injury cases, applying the crosswalk to hospital data from Massachusetts, Vermont, and New York[50].

Both WC and external cause codes can help to maximize the identification of work-related injuries, but there is clear reason for caution when using either method. WC payers have particularly **low sensitivity** for **agricultural injuries**, which are often not

covered by WC insurance[11,12]. From the Iowa Trauma Registry, the sensitivity of the WC payer to identify agricultural work-related injuries was just 19%, compared to 65% for rural nonagricultural work-related injuries[11]. WC is even less likely to identify work-related injuries for **older workers** as payment increasingly shifts to other insurance like Medicare [11,13].

While external cause codes are less dependent on payer, they are **not required** by most administrative databases, and some studies note 8-10% of injury records may be missing external cause codes[45,53]. One study noted that only 62% of records had more than one external cause code, suggesting many injuries have an incomplete picture of their circumstances[45]. When present, external cause codes may also bias a study toward specific types of injuries, particularly those that are informative to reviewers as "work-related", such as contact with agricultural machinery. This was noted by Bush et al, who found that 63% of ED visits with WC as payer did not contain a code from the work-related crosswalk[41]. Unless flagged by WC, this leaves potential for a more generic cause (e.g. "fall on same level") to be missed over a work-related cause (e.g. "fall from scaffolding").

Data gaps related to undercounting of older worker injuries

Occupational injury data may be undercounted through both surveillance activities and underreporting to workers' compensation databases[16,17]. The existing literature suggests that accurate estimates of work-related injuries are best achieved by combining available data to use multiple work-related indicators, while also assessing their overlap. However, these methods **have not been widely applied** to study occupational injuries in the elderly. Cost shifting to Medicare suggests that Medicare claims may be a useful data source to study occupational injuries in the elderly. One

study has thus far attempted to identify work-related injuries and illnesses in **Medicare claims**, although this study likely underestimated the burden as WC was used as the only source for ascertaining work-related information[51]. This leaves potential for further study of work-related ICD codes in Medicare, along with the WC indicator. As such, a focused study is needed to explore work-related ICD-10-CM codes and further define work-related injury cases among elderly Medicare beneficiaries.

2. Healthcare costs to older adults for work-related injuries

Work-related injuries can pose a significant cost burden to workers[54]. For older workers, workers' compensation and Medicare become highly relevant to patient costs, as **WC is intended to pay before Medicare** for work-related injuries[55]. WC payment can reduce healthcare costs for Medicare beneficiaries, who may have trouble paying high Medicare deductibles and coinsurance[51,56]. Without WC coverage, the burden of payment may be higher for public insurance and patients[57].

When WC does not pay, costs often shift to Medicare and likely impact beneficiary out-of-pocket costs[10,11,13,54]. In hospital data from California, Colorado, and New York, Medicare was found to be the most common payer of industrial injuries for older adults (57% in CA, 43% in CO, and 49% in NY)[13]. Similar evidence of a cost shift has been found with the Iowa Trauma Registry, where only 7% of agricultural work-related injuries were billed to WC for the 65 and older age group[11]. Even when WC coverage is present, it may be insufficient, and patients may later incur higher costs on other health insurance[54].

In light of this cost shift, other barriers to WC coverage are also likely to impact the healthcare cost burden for older workers. Workers may experience barriers to WC

coverage by gender, income, education, race and ethnicity, and immigration status, as well as working in non-standard jobs[9]. Agricultural workers may be less likely to receive WC medical or wage benefits, such as in Michigan, where workers' compensation was the payer on 24% of work-related farm injuries from hospital and outpatient records, and only 5% of these injuries linked to a wage replacement claim from the state WC database[12]. Workers may experience reporting barriers, including fear of retaliation, a perceived lack of severity, or lack of knowledge of the WC process[52,58].

As work-related injury costs shift to patients' primary health insurance, medical expenses and healthcare utilization tend to be higher with age and for female patients, as well as racial and ethnic minorities[54,57]. Rural work-related injuries tend to have greater cost and lost time from work than non-rural work-related injuries[59]. Low income patients are also impacted, as they are more likely to have their work-related injuries seen at a hospital, which may be more costly than an office or clinic visit[60].

Lastly, it is important to consider clinical factors, particularly measures of severity, when predicting patient costs for work-related injuries. Higher medical costs are associated with injury severity score, hospitalization, and higher levels of trauma care[11,59]. Injury severity score is also positively associated with both disability and medical costs[59,61]. In a study of agricultural WC claims from 14 states, 2/3 of claims were for medical costs and 1/3 were for death and disability, although death and disability claims accounted for 96% of total costs[61]. These strong associations between severity and cost may confound associations between medical costs and other patient factors such as rurality, age, or income[59,60]. It is also worth noting that less

severe injuries can also contribute significantly to the healthcare burden, as 53% of work-related injuries may be treated outside of a hospital[60].

Data gaps related to older adults' healthcare costs for work-related injuries

There has been limited exploration outside of workers' compensation to understand the costs of work-related injuries to other payers and to the patient. While studies have shown a cost shift to Medicare, only one study has descriptively summarized Medicare payments and beneficiary responsibility on Medicare claims where WC is payer[51]. The study did not attempt to identify incident injuries from past injuries (perhaps prior to turning 65), which prevents some generalization of the findings to older workers. This study was limited by only considering WC as a work-related factor, potentially missing ICD-10-CM codes or other indicators. Work-related injuries without WC coverage may be more costly to beneficiaries and Medicare. In addition, while the literature has identified demographic, socioeconomic, and clinical factors that can influence medical costs, many of these studies estimate costs to insurance rather than patient out-of-pocket amounts. The process of Medicare billing varies greatly by benefits, the level of care, and payers involved, which necessitates a focused study of factors that influence older workers liability through Medicare.

3. Job lock, work arrangements, and work-related injuries

Age-related changes can alter how well a person's skills and abilities match specific job requirements, creating a mismatch that may affect worker health outcomes[62,63]. Aging workers may benefit from making personal changes to their job situation, improving satisfaction and overall fit with the job[62,64]. Improved job fit can positively impact older workers' safety at work[17]. However, economic barriers can **limit**

job mobility in the elderly and may prevent this individualized process[3]. Reduced job fit may place older workers at greater risk of an occupational injury, while potentially beneficial changes, such as switching to part-time work, may be prevented by financial constraints[3,17,65,66].

Both income and job-related health insurance have been suggested as reasons that older workers remain in full-time work, **creating a job lock situation**[3]. Chronic illness may contribute to job lock and limit workers in their job transitions[67,68]. Workers with chronic illness or a chronically ill family member are less likely to leave their job if they rely on an employer for health insurance[68]. This has also been observed among cancer survivors, who are less likely to change jobs, reduce to part-time, or stop working if they have job-related health insurance[67]. Being older, married, working full-time, or living in a region with high unemployment may also prevent workers from making job transitions, even when they are dissatisfied with their job[64].

Job lock and similar measures of job mobility have been studied in terms of health outcomes, with varying results. Job lock is **relatively common among older workers** and may contribute to return to work problems, post-injury[69,70]. Remaining in a job for income has been associated with reduced life satisfaction and other wellbeing measures[3,71]. Job lock has also been investigated as a potential source of job stress, and among older Black workers job lock was associated with greater symptoms of insomnia[72]. Outside of the US, improved job mobility was found to predict greater psychosocial health and less personal and work-related burnout among Swedish workers[73].

Work arrangements are closely related to job lock and may further suggest occupational injury risk factors in the elderly. From the National Longitudinal Youth

Survey, among now working-age adults, jobs with overtime, shifts over 12 hours, and 60+ hour work weeks were found to increase the hazard rate of a work-related injury or illness[74]. Using the same survey, a different study examined within-person changes in work hours, noting that increased hours also increased the likelihood of a work-related injury or illness[75]. A notable exception was found among EMS workers, where extended weekly hours did not increase the risk of a work-related injury or illness, but part-time work was a protective factor, possibly by reduced exposure to hazards during the shift[66]. Further research highlights how the **arrangement of working hours, not just total hours**, can have dire impacts. From the US mining industry, a study of over 30 years of health and safety reports found injuries during longer shifts to be more likely to be fatal or involve injuries to multiple workers[76]. Irregular shift starts as well as contractor employment were also associated with injuries during these long working hours[76].

Data gaps related to job lock and work arrangements

The literature on job lock and work arrangements is often limited to self-reported health outcomes, which may be prone to bias[3,71,72]. Job lock studies are also often cross sectional or use a short follow-up period to identify an outcome[3,72]. No study has explored the longitudinal risk of job lock on occupational injury, yet, studies have reported that job lock is common among injured workers and may be a risk factor for injury[69,70]. Similarly, work arrangements are highly relevant to older workers, who may be impacted by longer shifts, full-time vs part-time status, and increased weekly hours, although the current literature has not focused on older workers[74–76]. A longitudinal study, using both self-reported and administrative data sources, may help to

reduce bias and improve estimates of how job lock and work arrangements impact the risk of work-related injury for older workers.

SUMMARY

Occupational injuries are a significant source of morbidity and mortality among older workers and may impact older adults financially. Older workers may also be at risk of occupational injuries through economic circumstances and their work arrangements. The literature provides methods to identify work-related injuries from administrative databases using payers and ICD-10-CM external cause codes. This lays the groundwork to explore work-related injuries and their costs among older adults, using healthcare databases such as Medicare. Thus far, limited descriptive statistics are available for work-related injuries and illnesses to older adults on Medicare, only where workers' compensation is a payer. Further study of Medicare claims can help to elucidate costs of work-related injuries to older adults, as well as factors that influence these costs. Linking job-related exposure data to longitudinal healthcare data such as Medicare may help to improve estimates of how economic factors and work arrangements influence the risk of work-related injuries to older workers.

Chapter 3: Manuscript 1

Incidence of work-related injuries among Medicare fee-for-service enrollees, 2016-2019

Abstract

Background: Work-related injuries are under-reported among older workers, due to limitations from data sources like workers' compensation claims or hospital records. We analyzed Medicare administrative claims data to identify and describe work-related injuries among aged Medicare enrollees.

Methods: We first identified injury claims from 2016-2019 Medicare Inpatient and Outpatient claims, among fee-for-service Medicare enrollees aged 65 and older. Work-related ICD-10-CM codes, along with employment-related and workers' compensation codes used in Medicare claims processing were then applied to injury claims. From these work-related injury claims, we further describe enrollee demographics, injuries and their mechanisms, and healthcare encounter characteristics.

Results: The average annual incidence from Medicare claims was 27.6 work-related injury claims per 100,000 Medicare fee-for-service enrollees aged 65 and older. Injury claims were most often for outpatient ED visits (58%), non-ED outpatient visits (20%), or hospitalizations (19%). The most common mechanisms of injury were falls, transportation, and machinery-related mechanisms, each accounting for 20% of injuries.

Conclusion: Medicare claims have the potential to identify work-related injuries based on the mechanism of injury or employment-related codes used in Medicare claims processing, in addition to workers' compensation codes. Most injuries were identified from outpatient settings, although hospitalizations appeared to involve the most

extensive care. Future research may seek to validate or expand on these methods, as well as study the costs and health outcomes of work-related injuries in this population.

Introduction

As the number of older workers in the US is expected to increase – by 2030 nearly 1 in 3 adults age 65-74 may be employed – there is an imperative to understand and mitigate the occupational injury burden in the aged population[77]. In 2019, the fatal work-related injury rate was 9.4 fatal work injuries per 100,000 FTE for workers aged 65 and older, more than twice the rate of the next highest age group, workers aged 55-64, with 4.6 fatal work injuries per 100,000 FTE[78]. Older workers often have injuries seen more broadly in the elderly, such as falls, which account for about half of the non-fatal occupational injuries and illnesses to workers age 65 and older[79].

Occupational injuries may be poorly captured in electronic records used for surveillance. This makes surveillance challenging for older adult work-related injuries. Much of what we know about injuries to older workers comes from secondary data sources maintained by the U.S. Bureau of Labor and Statistics (BLS) - the BLS Survey of Occupational Injuries and Illnesses (BLS SOII) and the Census of Fatal Occupational Injuries (CFOI)[78,79]. Although it is perhaps the most widely known surveillance system for occupational injuries, the BLS SOII likely undercounts non-fatal injuries since it relies on accuracy of employer reporting and excludes certain groups such as self-employed workers, workers on farms with fewer than 11 employees, and federal government workers[80,81]. Studies find employers may even underreport work-related injuries to the BLS SOII[38–40].The survey may be particularly limiting for older adults, who often engage in non-traditional work arrangements such as self-employment or volunteering[24,82]. More is likely known on workplace fatalities, since the CFOI

identifies and substantiates fatal work injuries from a number of source records including death certificates, workers' compensation reports, and medical examiner reports[81].

Other secondary administrative data sources are increasingly used for surveillance but also come with limitations. In the United States, workers' compensation (WC), which provides medical and wage benefits to employees who are injured from work, is often used to detect occupational injuries[11,12,45,47,48,61]. However, WC likely underestimates work-related injuries since not all workers have access to WC coverage, and barriers to coverage exist such as fear of workplace retaliation or lack of knowledge of benefits[58]. Hospital discharge and emergency department records, collected at the state level, may also use work-related causes from ICD-9-CM/ICD-10-CM codes, as well as WC from the "expected payer" on the record[13,41,45,49,50]. These methods are still limited for older workers, who are less likely to have their injuries covered by WC, and for who work-related external causes have not been specifically studied[11,13]. Studies using these databases often report a lack of a unique patient identifier, preventing an accurate count of the individuals who make up their "cases"[41].

Medicare, which provides health insurance to over 60 million adults age 65 and older in the US, may provide a more comprehensive source of injury data to overcome limitations of existing surveillance systems[83]. Medicare claims have the potential to identify work-related injuries in several ways. They include both ICD-10-CM codes as well as primary payer data to identify workers' compensation, as well a unique enrollee identifier for an individual case count[84]. Medicare enrollees are in either traditional Medicare, in which healthcare providers submit claims to Medicare for reimbursement (fee-for-service), or a Medicare Advantage plan from a private insurer[85]. Medicare fee-for-service claims cover over half of all Medicare enrollees and provide a first step to explore older worker injuries in Medicare[83]. Only one study, to our knowledge,

provides an overview of work-related injuries and illnesses in Medicare claims, but only where WC is the payer[51]. A comprehensive approach to apply occupational injury surveillance methods to Medicare claims could help to calculate an incidence rate and further our understanding of work-related injuries in this older adult population.

In this study, we analyzed Medicare claims data to describe the incidence and burden of work-related injuries in the age 65 and older Medicare fee-for-service population in the US. After identifying injury claims from 2016-2019 Medicare Inpatient and Outpatient claims data, we describe a process to identify a subset of work-related injuries based on workers' compensation payer and ICD-10-CM codes. Following this, we estimate the incidence of work-related injury hospitalizations, emergency department visits, and outpatient facility visits for older adults on Medicare. Lastly, we summarize enrollee demographic characteristics and the causes, types of injuries, payer, and other healthcare encounter characteristics.

Methods

Data source and eligibility criteria

Medicare enrollee data: We used annual Medicare fee-for-service claims and enrollment data from 2016-2019. In each calendar year, we limited enrollment data to enrollees who were at least 65 years old, resided in one of the 50 US states or DC, and were continuously enrolled in fee-for-service Medicare Parts A and B for all months of the year in which they were alive. Those who turned 65 mid-year were included as long as they had this continuous enrollment going forward. We excluded those enrolled in managed care plans.

Medicare claims: Enrollees meeting the age and enrollment criteria were then joined to their Inpatient and Outpatient claims data recorded between January 1, 2016 and December 31, 2019. These files represent claims submitted by facilities to bill

Medicare Part A insurance, for inpatient care in hospitals, and Part B, which covers outpatient medical care and certain inpatient services[86]. These claims were largely submitted by hospitals and are comparable to hospital discharge or emergency department data used in surveillance[87,88]. They include ICD-10-CM diagnosis and external cause of injury data to identify the "initial encounter" for the injury or mechanism of injury, as required by CDC injury surveillance definitions[87,88]. From these eligible fee-for-service Inpatient and Outpatient claims, we selected potentially acute and traumatic work-related injuries billed through Medicare from 2016-2019, following the procedures detailed below.

Injury case definition

We included injuries resulting in hospitalization, an emergency department visit, or a non-emergency department hospital/clinic visit. We applied the CDC injury surveillance definition for emergency department visits to both inpatient and outpatient claims, which calls for an injury in any diagnosis position (ICD-10-CM S, T, O, and M codes), for an initial encounter, or at least one external cause of injury code (V00-V99, W00-X58, X71-X83, X92-Y09, Y21-Y33, Y35-Y38) for an initial encounter[87,88]. The definition excludes injuries for subsequent encounters and sequelae. The CDC uses a stricter hospitalization definition, requiring an injury principal diagnosis, but we chose to apply this singular definition in order to identify a broad set of injuries and make comparisons between inpatient and outpatient claims[87].

Work-related ascertainment in claims data

We used two processes to ascertain work-relatedness of each injury claim. For the first process (Method 1 - WC Indicator), we examined the five ways that a workers' compensation payment or th*e potential* for workers' compensation payment can be identified from Medicare claims[84]. These codes, which are used in Medicare claims

processing to determine if Medicare is a secondary payer to workers' compensation, as well as indicate a payment from workers' compensation, are summarized in **Table 1**[55].

For our second process, (Method 2 - ICD Indicator), we analyzed ICD-10-CM External Cause codes from each claim, found in claim diagnosis and "E code" fields (**Table 1**). Prior research has identified specific ICD-10-CM external causes of morbidity codes for a mechanism, activity, place, or status that possibly indicate a work-related or agricultural injury[41,50]. We compiled these codes into a list of work-related injury codes, excluding several codes from the list that correspond to occupations unlikely to involve older workers (e.g. military) or unlikely to be work-related if seen in the elderly, such as codes involving "merchant ships", which we decided could potentially indicate passengers rather workers. We then searched both diagnosis and external cause code variables on the claim for this list of codes (see **Appendix**). We considered any injury claim with at least one of these external cause codes to be work-related.

Table 1. Medicare claim fields and sources for work-related claim ascertainment.

Claims data element	Value/Description
Primary Payer Code	'E' / Workers' compensation paid claim
Claim Value Code	15 / Higher priority WC plan. Claims may have a Medicare "conditional" payment, before a WC settlement
Claim-Related Occurrence Code	04 / Employment-related "accident"
Claim Condition Code	02 / Employment-related "condition"
Medicare Non-Payment Reason Code	14, 15 / Workers' compensation is the reason for a Medicare claim denial
Claim Diagnosis E Code / Claim Diagnosis Code	Work-related / agricultural ICD-10-CM codes[41,50]

Demographics

From Medicare enrollment data, we used age, race/ethnicity, county and state of residence, and Medicaid enrollment variables. We grouped age from a continuous variable into categories (65-69, 70-74, 75-79, 80-84, 85+), while sex (male/female) and race/ethnicity (White, Black, Asian, Hispanic, North American Native, Other, Unknown) were kept as they appear on the record. We categorized enrollee county of residence as rural and metropolitan based on rural-urban continuum codes[89]. State was grouped into Census region (Northeast, Midwest, South, West)[90]. Medicaid enrollment was used as a proxy for low income. For these individuals, Medicare is their primary insurer, although they often qualify by income for some healthcare benefits from their state Medicaid program[91,92].

Healthcare encounter

We categorized inpatient and outpatient claims by facility type (hospital, outpatient facility, rural health clinic). We noted accommodations and services provided during the stay based on revenue center billing for the emergency department, intensive care unit, operating room, radiology, respiratory services, blood administration, and occupational or physical therapy[93,94]. For inpatient claims, we calculated the length of stay as the number of days between the admission and discharge dates on the claim. For all claims we examined the discharge status (i.e. home/self care, transferred to another hospital, transferred to post-acute care facilities, expired in the facility). Lastly, we categorized each claim by the primary payer code, either Medicare, workers' compensation, employer-group health plans, no fault automobile insurance, and "other" insurance (Black Lung Program, the Department of Veteran's Affairs, or other liability insurance).

Data analysis

After pooling the claims meeting all the definitions above, we estimated an annual incidence rate of work-related injuries among Medicare fee-for-service enrollees age 65 and older, as the total number of work-related injury claims per 100,000 aged fee-for-services enrollees enrolled in each year[95]. We then produced descriptive analyses of mechanisms of injury, types of injuries, demographic characteristics, and characteristics of the healthcare encounter, stratifying on inpatient and outpatient status. We characterized injuries using the ICD-10-CM Injury Mortality Matrix, by nature and body region of the injury[34,36]. We analyzed mechanisms of injury using the ICD-10-CM External Cause Matrix[96,97].

Results

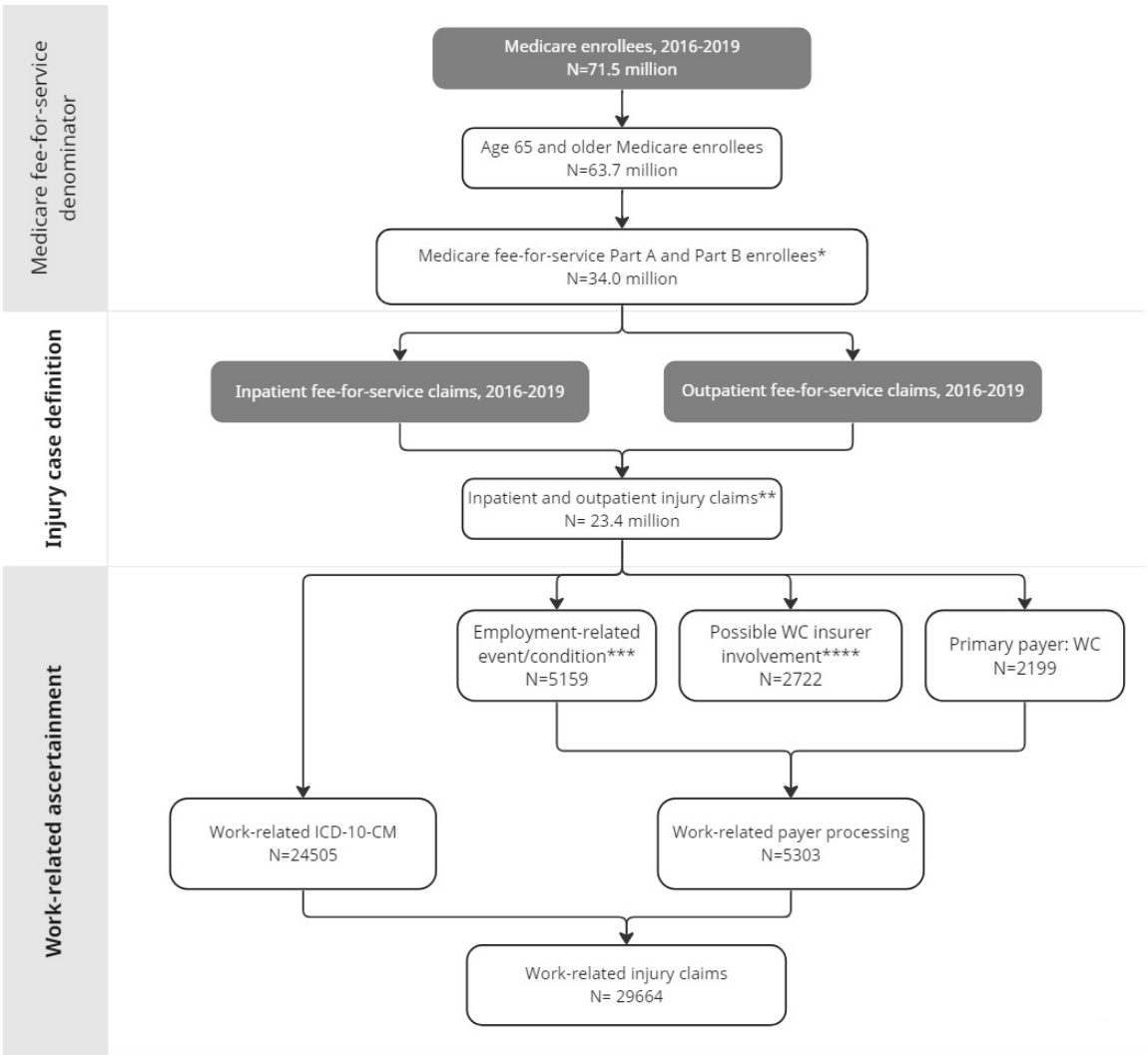
Work-related injuries identified by method

From 2016-2019, among 34.0 million aged Medicare fee-for-service enrollees we identified 23.4 million inpatient and outpatient claims that met the injury definition (**Figure 1**). From these claims, we identified 5091 work-related injury claims by Method 1 (WC indicator) and 24549 claims by Method 2 (ICD indicator). The two methods had minimal overlap in claims, and only 0.5% (N=144) of work-related injury claims met the criteria of both methods. In total, we kept 29664 work-related injury claims for further analysis, representing 27471 unique enrollees, for an average of 1.1 claims (SD=0.5) per enrollee.

By work-related ascertainment method, most claims from Method 1 (WC Indicator) met the criteria with an employment-related occurrence or condition (97.3%). WC was often indicated by the claim value code (49.9%) and/or primary payer code (41.5%). By Method 2 (ICD Indicator), the most common work-related external cause codes were for contact with agricultural machinery (N=4680, 19.1%), building and

construction activities (N=4303, 17.6%), occupants of agricultural vehicles injured in transport incidents (N=3218, 13.1%), and civilian activities done for income or pay (N=3305, 13.5%). Transportation incidents involving ambulance and bus drivers, occupants of heavy transport vehicles, or occupants of special construction vehicles formed a sizeable group as well (N=1907, 7.8%).

Figure 1. Work-related injury ascertainment process from Medicare Inpatient and Outpatient fee-for-service claims, 2016-2019.

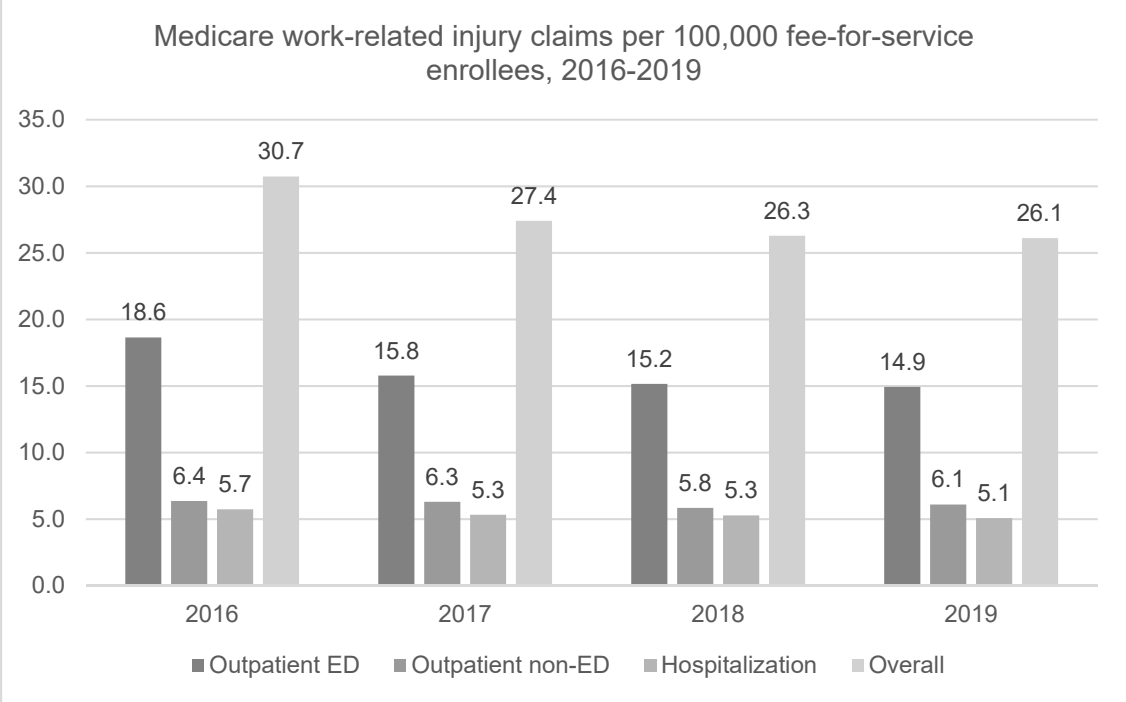


*Continuous annual enrollment in Medicare fee-for-service Part A and Part B
**Injury claims: Inpatient or Outpatient claim with ICD-10-CM diagnosis of injury (S, T, M, O codes), initial encounter, in any diagnosis position OR an ICD-10-CM external cause of injury, initial encounter
***Employment-related occurrence/condition code / ****Claim value code for WC

Incidence rate

From 2016-2019, we calculated an annual incidence of work-related injuries of 26.1-30.7 work-related injury claims per 100,000 Medicare fee-for-service enrollees. Outpatient ED claims were the largest contributor, accounting for 57.2-60.7% of incident cases in any given year, followed by outpatient non-ED claims and inpatient hospitalizations (**Figure 2**). Incidence declined by 15.1% over all in the four-year period, mostly in 2016-2017, with a 15.4 decline in outpatient ER visits and a 7.2% decline in hospitalizations.

Figure 2. Incidence of Medicare work-related injury claims by age 65+ denominator population, 2016-2019.



Injury characteristics

Overall, 60.7% of work-related injury claims had a fall, machinery, or transportation-related cause. Another 20.9% of claims listed other causes as found in **Table 2**, and 18.4% of claims were missing cause information. Of claims with causes, 98.9% were unintentional. Compared to outpatient claims, inpatient claims had a higher proportion of falls (27.3% vs 18.7%), and non-traffic motor vehicle causes (16.9% vs 10.5%)(**Table 2**). Of less common causes, those for struck by/against, cut/pierce, overexertion, natural/environmental causes, or bites and sting injuries were found on 14.1% of outpatient but only 5% of inpatient claims.

Claims frequently reported multiple injuries, most often to the upper/lower extremities (72.1% of claims), followed by the head/neck (30.9%), torso (24.3%), and the spine/back (9.3%). Injury claims most often involved a fracture (28.5%), superficial injury/contusion (25.8%), open wound (25.3%), sprain/strain (13.1%), internal organ injury (8.0%), or a burn (4.3%). Among inpatient claims (N=5759), the most common principal diagnosis was a hip fracture (11.3%), followed by traumatic brain injury (9.0%), chest fracture (7.4%), lower leg/ankle fracture (6.2%), and an injury to chest internal organs (4.9%). The most common principal diagnosis on outpatient claims (N=23905) was an open wound to the wrist, hand, or fingers (9.6%), open wound to the head (3.5%), fracture of the wrist, hand, and fingers (2.8%), chest fracture (2.7%), and open wound to the lower leg and ankle (2.6%).

Table 2. ICD-10-CM external causes of injury present on work-related injury claims (N=29664)*.

	Inpatient claims	% of claims	Outpatient claims	% of claims
Falls	1575	27.3%	4462	18.7%
Machinery	1226	21.3%	4744	19.8%
Transportation				
Motor vehicle: traffic	527	9.2%	1646	6.9%
Motor vehicle: non-traffic	974	16.9%	2520	10.5%
Other transport	54	0.9%	546	2.3%
Struck by/against	142	2.5%	1314	5.5%
Cut/pierce	59	1.0%	950	4.0%
Overexertion	< 11	< 0.2%	592	2.5%
Natural/environmental, other	60	1.0%	302	1.3%
Bites and stings	< 11	< 0.2%	197	0.8%
Hot object/substance	24	0.4%	79	0.3%
Fire/flame	81	1.4%	66	0.3%
Firearm	13	0.2%	< 11	< 0.1%
Other specified causes	18	0.3%	1428	6.0%
Unspecified	80	1.4%	641	2.7%
Missing mechanism	735	12.8%	4576	19.1%

*Mechanism counts may exceed total as some claims have more than one mechanism of injury

Demographic characteristics

Overall, enrollees with work-related injuries had a median age of 72, and were mostly male (74.8%) compared to female (25.2%) (**Table 3**). Enrollee race/ethnicity was more often reported as White (90.1%) compared to Black (4.9%), Hispanic (1.0%), Other (0.8%), North American Native (0.7%), or Asian (0.6%), or Unknown race/ethnicity (1.9%). Overall 8.6% of enrollees were dual eligible for Medicaid. Enrollees resided more often in metropolitan over rural counties (57.9% vs 42.1%), as well as the Southern (37.6%) or Midwest (32.1%) region of the US. Admitted enrollees were more often age 75 or older (45.1%) compared to outpatient (34.4%), male (80.2% vs 73.7%), or residing in a metropolitan area (59.3% vs 57.4%) (**Table 3**). Outpatient visits saw a higher

proportion of enrollees age 65-69 (38.7% vs 29.6%) and a higher proportion of Black enrollees (5.3% vs 3.2%).

Table 3. Demographic characteristics of Medicare enrollees with work-related injuries (N=27471), by claim source.

	Inpatient claims		Outpatient claims	
	Enrollee N	% of Enrollees	Enrollee N	% of Enrollees
Demographic characteristics				
Age				
65-69	1666	29.6%	8593	38.7%
70-74	1427	25.3%	5963	26.9%
75-79	1116	19.8%	3893	17.5%
80-84	794	14.1%	2247	10.1%
85+	630	11.2%	1505	6.8%
Sex				
Male	4515	80.2%	16367	73.7%
Female	1118	19.8%	5834	26.3%
Race/ethnicity				
White	5186	92.1%	19900	89.6%
Black	180	3.2%	1175	5.3%
Asian	38	0.7%	126	0.6%
Hispanic	42	0.7%	223	1.0%
North American Native	31	0.6%	164	0.7%
Other	53	0.9%	175	0.8%
Unknown	103	1.8%	438	2.0%
Medicaid dual				
Yes	505	9.0%	1880	8.5%
No	5128	91.0%	20321	91.5%
County of residence				
Metro	3341	59.3%	12736	57.4%
Rural	2292	40.7%	9465	42.6%
Census Region				
Northeast	891	15.8%	3344	15.1%
Midwest	1679	29.8%	7256	32.7%
South	2247	39.9%	8244	37.1%
West	816	14.5%	3357	15.1%
Total enrollees*	5633	100.0%	22201	100.0%

*Individuals may appear in both inpatient and outpatient columns (N=363, 1.3%)

Healthcare encounter characteristics

Most injuries were seen in the outpatient emergency department setting (58.3%), admitted to the hospital (19.4%), or seen a non-ED hospital setting (16.1%), rural health clinic (5.1%), or other outpatient facility (1.3%). Occupational/physical therapy, respiratory services, and blood administration were more common to inpatient claims (**Table 4**). Over half of hospitalizations involved either the ICU (41.0%) and/or the operating room (49.5%), many lasting for three or more days (70.7%)(**Table 4**). Stays involving the ICU tended to last longer and had more services. The average length of stay was 5.9 days (SD=8.4), but with ICU stays averaged 8.0 days (SD=8.9). Respiratory services were far more common when ICU was present (56.3% of ICU stays vs 23.3% of non-ICU stays), as well as blood administration (29.0% of ICU stays vs 4.9% of non-ICU stays). Inpatient stays most often ended in a transfer to post-acute care (51.8%). For both inpatient and outpatient claims, 1.1% of claims showed that the patient expired in the facility, matching to a date of death on the enrollment record. Medicare was usually the primary payer of work-related injury claims (89.0%), followed by WC (7.4%), and 3.6% by other types of insurance.

Table 4. Encounter characteristics of work-related injury claims by admission status (N=29664).

	Inpatient claims		Outpatient claims	
	N	% of Claims	N	% of Claims
Total claims	5759	100.0%	23905	100.0%
Encounter setting				
Hospital - ED	5018	87.1%	17307	72.4%
Hospital – non-ED	741	12.9%	4751	19.9%
Rural health clinic	0	0.0%	1519	6.4%
Other facility	0	0.0%	328	1.4%
Accommodations and services				
Intensive care unit	2359	41.0%	0	0.0%
Operating room	2851	49.5%	1091	4.6%
Radiology	5041	87.5%	11773	49.2%
Occupational/physical therapy	4629	80.4%	833	3.5%
Respiratory services	2159	37.5%	320	1.3%
Blood administration	1185	20.6%	63	0.3%
Length of stay (Inpatient only)				
1-2 days	1678	29.1%		
3-7 days	2835	49.2%		
8-14 days	816	14.2%		
15-30 days	324	5.6%		
30+ days	94	1.6%		
Discharge indicators				
Home	2269	39.4%	22841	95.5%
Hospital transfer	155	2.7%	396	1.7%
Transfer to post-acute care	2985	51.8%	212	0.9%
Other / unknown	99	1.7%	177	0.7%
Expired	250	4.3%	70	0.3%
Payers				
Medicare	4761	82.7%	20911	87.5%
Medicare conditional payment	199	3.5%	543	2.3%
WC	560	9.7%	1639	6.9%
EGHP	89	1.5%	470	2.0%
No fault auto	131	2.3%	298	1.2%
Other	19	0.3%	44	0.2%

Discussion

Summary

In this descriptive study, we estimated an average annual incidence of 27.6 work-related injuries per 100,000 Medicare fee-for-service enrollees aged 65 and older in the US. These injuries mainly involved fall, transportation, or machinery-related mechanisms, often related to agriculture. Over half of enrollees were aged 65-74, the fastest growing age demographic among US workers[77]. Most injuries were seen in the outpatient ED, although hospitalizations took up a large share of the healthcare burden. Medicare appeared to be the payer for the majority of work-related injury claims.

Incidence estimate

From 2016-2019, we observed a 15% decline in the rate of work-related injuries, although rates were more stable in the last two years of the study period. This trend could reflect an actual decline in work-related injuries in this population, consistent with BLS CFOI reports showing that the age 65+ fatal work-injury rate declined by 19% in this same time period[78]. However, most of the decline occurred from 2016-2017, just after Medicare switched from the ICD-9-CM to the ICD-10-CM coding system on October 1, 2015[98]. In line with the switch, only cases found by Method 2 (ICD) decreased with time, suggesting this may be an artifact of the coding switch.

For this age group, Medicare inpatient and outpatient claims had fewer work-related injuries than nonfatal work-related injuries and illnesses reported in BLS, with the exception of agricultural cases[79]. While BLS reported 163130 nonfatal cases from 2016-2019, we identified 18.2% as many work-related injuries from Medicare during this time[79]. However, only 1960 of the BLS-reported nonfatal cases were to agricultural workers age 65 and older, and we identified 7898 cases by agricultural mechanism alone, plus 2146 injuries occurring on the farm[79].

Overall, we likely missed many work-related injuries, simply by not covering the managed care population, around 40% of Medicare[83]. Some Medicare enrollees who were still working may have waived Part B coverage, being excluded from our study. Also, our method would exclude some injuries with general causes, such as "fall on same level", while BLS can capture these from employers[99]. With regard to agriculture, our results emphasize potential over the BLS. Medicare enrollees incurred over five times as many agricultural injuries as BLS, which SOII could miss since it does not cover small farms, self-employed, or family workers[79].

Demographic characteristics

Work-related injury incidence decreased with age, and the 65-74 age group averaged 31.4 cases per 100,000 enrollees, compared to 22.9 cases per 100,000 enrollees in the 75 and older group. These rates may reflect higher employment close to age 65[19]. Meanwhile, those aged 75 and older, were hospitalized for 25% of their work-related injuries, compared to 18% in the 65-74 age group. Hospitalization is a measure of severity in occupational injuries[100]. In geriatric trauma enrollees, Injury Severity Score, complications, and mortality also tend to increase with age[101]. Although studies often report lower rates of occupational injury with age, in this aspect the occupational disease burden seems more serious for older adults[17,18].

We also noted 47.6 work-related injuries per 100,000 male Medicare enrollees, compared to 12.1 work-related injuries per 100,000 female Medicare enrollees. Male enrollees were also hospitalized 21.6% of the time, compared to 16.1% of female enrollees. This aligns with past studies that observe work-related injuries more often among male than female enrollees, and in a recent study of work-related farm injuries, male enrollees were also more likely be hospitalized[11–13,45,102]. The cohort was also mostly reported as White, which could reflect how Medicare data undercounts those who

self-identify as Hispanic, Asian, Pacific Islander, or American Indian[103]. This raises concern that Medicare could underestimate the impact of occupational injury with regard to race or ethnicity. Lastly, we saw differences in rural areas, where only 23% of Medicare enrollees reside, but where we found 42% of work-related injuries[104]. While Medicare offers limited demographic data, our findings seem notable for rural areas, where agricultural injuries may be cost shifted to Medicare[11].

Injury and encounter characteristics

We found 1 in 5 injuries to involve a fall, and hip fractures were the most frequent reason to be hospitalized, both common injuries to older workers and the broader elderly population[99,105,106]. However, fractures (28.5% of work-related injury claims) overall were more common in our study than reported by other sources, while sprains and strains were relatively less common (13.1%) than other sources. In North Carolina, just 8.7% of work-related injuries to those aged 16 and older were for fractures from 2010-2013, while 24.0% of visits were for sprains and strains, although notably the study only used an outpatient (emergency department) data source[45]. Possibly, by including hospitalizations more severe fractures may have overshadowed the sprains and strains in our study, seeing as 46.1% of fractures, but only 5.3% of sprains and strains were hospitalized.

Hospitalizations seemed to have the most severe cases in our study, often involving the head/neck, chest, or abdomen, which would suggest higher severity on the Abbreviated Injury Scale[107]. These cases often involved ICU, usually lasting over three days, which can be indicative of major trauma[108]. Notably, 23% of admissions appeared to have received blood. Although we could not assess the timing, receiving a blood transfusion within four hours of hospital arrival has also been suggested as an

indicator of major trauma[108]. Compared to outpatient visits, hospitalizations were also associated with higher mortality and transfers to post-acute care.

Strengths and Limitations

A major strength of our study is the comprehensive set of methods used to ascertain work-related injuries in this older population. Using data from Medicare, the largest healthcare insurer of older adults in the US, we mitigate some bias from detecting work-related injuries with only WC payer or hospital data. Our findings support past research that workers' compensation underestimates work-related injuries among older adults[11,41]. We also add nuance, finding 17.4% of work-related injuries showed Medicare was alerted to an employment-related claim, while only 7.4% showed a WC payment, and a smaller 1.8% had a conditional Medicare payment. Workers may experience barriers to WC coverage by gender, income, education, race and ethnicity, immigration status, or by having non-standard employment[9,58]. Future research may seek to explore these barriers further in the Medicare payment process.

There are several limitations to this study. Unlike past studies with administrative data, we found very little overlap in our two methods of ascertainment. Even with a very likely work-related ICD-10-CM code in our study, a "civilian activity done for income or pay", only 3% of claims showed WC payment. Potentially, previous studies underestimate the proportion of work-related injuries paid by Medicare[55]. However, since Medicare data is captured at a specific point in time, it is possible that more injury claims were later settled by WC and missed by our method[84].

Our incidence rates may underestimate the risks of injury from work in the age 65 and older population, as they are only generalizable to the Medicare fee-for-service population, and without an employment denominator for Medicare, they may be less accurate for older workers. If we were to recalculate the incidence, assuming a similar

employment rate as BLS, the annual incidence would be estimated at around 150 work-related injuries per 100,000 aged, working Medicare enrollees[109]. Also, by using the CDC injury definition for emergency department visits, we could overestimate hospitalized injuries as defined by the CDC. The hospitalized injury definition requires principal diagnosis and would exclude 4335 (18.1%) of outpatient cases and 1011 (15.8%) of inpatient cases, including over 3000 falls, transportation, and machinery-related cases.

Lastly, our study is limited in that we only examined the "initial encounter" for a work-related injury. Medicare claims have an advantage over some existing surveillance systems in that enrollees can be followed longitudinally through claims. To provide simple estimates and tackle a complex topic, we determined enrollees' first instance of a work-related injury, but we analyzed each claim as a standalone encounter. We recognize that these claims may have been a person's first, often life-changing healthcare encounter for a work-related injury, resulting in multiple claims in the days, weeks, or months following the injury. To further understand the impact of work-related injuries on Medicare enrollees, future research may seek to use Medicare claims to study the timeline of enrollees' injuries, revealing a more complete picture of hospital transfers, readmissions, or follow up care.

Conclusion

As more adults continue working past the age of 65, work-related injuries continue to be a concern for this population. Using Medicare inpatient and outpatient claims, we provide estimates of the incidence of work-related injuries in the aged Medicare population. Our study finds that falls are an important mechanism to consider for work-related injury prevention in older adults, as well as agriculture-related transportation and machinery incidents. While most injuries were seen as outpatient

visits, we also found that injuries often appear quite severe and involve extensive hospital care. These injuries appear to largely impact adults aged 65-69 in the Medicare aged population, who are more likely to be working and possibly near the age of retirement. As in past research, we find that Medicare takes on a large portion of the payment burden for work-related injuries in the elderly, in comparison to workers' compensation. Future research may benefit from applying, validating, and expanding on these methods, carrying out analyses of the costs, complications, and outcomes of these injuries, or focusing on a subset of injuries such as agriculture, falls, or transportation.

Chapter 4: Manuscript 2

Effect of workers' compensation coverage on Medicare enrollee financial liability after a work-related injury.

Abstract

Background: For adults aged 65 and older in the US, healthcare costs of work-related injuries have largely shifted from workers' compensation (WC) to Medicare. We analyzed Medicare claims data to estimate short-term costs to Medicare enrollees for their work-related injuries, hypothesizing that enrollees would have fewer out-of-pocket costs if claims were initially paid by workers' compensation.

Methods: From 2016-2019 Medicare Inpatient and Outpatient fee-for-service claims, we identified a cohort of aged Medicare enrollees with work-related injuries. We then compared short-term costs to enrollees for inpatient, outpatient, and skilled nursing care. We used difference-in-differences, time series, and quantile regression to estimate the effect of workers' compensation coverage on 90-day claims and out-of-pocket costs.

Results: We identified 13039 aged Medicare enrollees with a work-related injury, of which 16% had some initial workers' compensation coverage for their injury. The WC group averaged $452 (95% CI 395, 509) in excess out-of-pocket healthcare costs following the injury, compared to $603 (95% CI 572, 634) for the non-WC group. At the 90th percentile of out-of-pocket spending, those without workers' compensation coverage incurred $601 in additional costs over the WC group (95% CI 398, 805).

Conclusion: Workers' compensation seems to protect Medicare enrollees from incurring some costs from Medicare coinsurance and deductibles, but most work-related injuries in Medicare claims do not seem to be covered. When Medicare claims have evidence of

a workers' compensation payer, enrollees still incur out-of-pocket healthcare costs in excess of their costs prior to the work-related injury.

Introduction

In 2019, over 10 million US adults were working past the age of 65 and sustained over 47,000 nonfatal cases of occupational injuries and illnesses[99]. Work-related injuries can place a financial burden on workers through healthcare costs and lost wages[10,54,59,61,110]. Workers' compensation (WC) is intended to help cover these costs, but it may be not be adequate or even available for all workers[54]. Older adults could end up paying for work-related injuries through their Medicare coverage, as the costs of work-related injuries have shifted from WC to Medicare[10,11,111]. However, Medicare is not intended to cover the costs of work-related injuries, and this cost shift could create disparities in the financial liability of older adults for their work-related injuries[55].

Nationally, less than half of medical costs for work-related injuries and illnesses appear to be covered by WC, with the remaining costs going to public and private insurance, as well as patients[10]. Studies have found that Medicare is a frequent payer of work-related injuries for older adults, even though Medicare is considered a secondary payer to workers' compensation[11–13,55]. In California, Colorado, and New York, Medicare paid for 43-57% of industrial injuries among older adults[13]. Agricultural injuries are less often covered[11,12]. In Michigan, workers' compensation paid for only 24% of farm-related injuries from hospital and outpatient records for adults aged 65 and older[12]. In Iowa, just 7% of rural, agricultural work-related injuries were billed to WC for this older aged group[11].

As a result of this cost shift from WC to Medicare, Medicare enrollees could have a high financial liability for their work-related injuries, relative to other age groups. Medicare already has high cost sharing for enrollees and does not cap out-of-pocket costs, leaving injured workers to accumulate high deductibles and coinsurance[16]. In 2019, the Medicare inpatient deductible reached $1364[112]. Emergency department or other outpatient visits may incur an outpatient deductible ($185 in 2019) and a 20% copay[112]. If further, post-acute care is needed, patients may owe $170/day after the first 20 days of skilled nursing care[112].

While workers' compensation is intended to protect workers from paying out-of-pocket costs for their work-related injuries, the direct effects of WC on Medicare enrollee costs are not yet understood. Past research has found group health insurance (GHI) claims to show high average monthly costs for patients after a WC claim is filed, suggesting that WC coverage was inadequate for their care[54]. A similar study found that patients with zero cost WC claims (i.e., filed claims with no payment by WC) had higher inpatient and outpatient costs on their group health insurance in the 2-3 months following an injury, compared to those with a claim that was actually paid by WC [110]. These studies suggest that WC does not entirely cover the cost of a work-related injury, since patients in these studies had increased healthcare costs billed to their personal health insurance after the injury, compared to before. However, these studies did not investigate effects among older adults.

Historic cost shifting to Medicare creates a need to study the extent to which workers' compensation covers injuries among older adults, including out-of-pocket Medicare costs[10,11,111,113–115]. In this retrospective cohort study, we identified patients with recent work-related injuries billed in Medicare administrative claims data,

and described their short-term healthcare costs from hospital, outpatient, and skilled nursing care. We then examined trends in utilization of inpatient, outpatient, and skilled nursing services before and after a work-related injury to estimate the relative impact of WC coverage on the use of these services over time. We hypothesized that following a work-related injury, short-term out-of-pocket costs would be lessened for Medicare enrollees if the Medicare claim was initially paid by workers' compensation. In doing so, we estimate the excess healthcare out-of-pocket costs incurred by older Medicare enrollees following a work-related injury, as well as the protective effects of WC coverage.

Methods

We used a case-only retrospective cohort study design to estimate the impact of workers' compensation coverage on Medicare enrollee out-of-pocket costs, as well the impact on inpatient, outpatient, and skilled nursing services billed to Medicare. We compared Medicare enrollees with and without their initial work-related injury claim paid by WC. We examined these services in the 90 days before and after the injury, in order to capture a possibly intense change in claims and costs immediately following the injury[54,110,116].

Medicare enrollee data: We obtained annual Medicare fee-for-service claims and enrollment data from 2016-2019. In each calendar year, we identified enrollees who were at least 65 years old, resided in one of the 50 US states or DC, and enrolled continuously in fee-for-service Medicare Part A, which covers hospital and skilled nursing care, and Medicare Part B, which includes outpatient care [13]. We excluded those on managed care plans to ensure complete claims for everyone in the cohort.

Medicare claims: We next joined these enrollees to their Medicare Inpatient and Outpatient claims data recorded between January 1, 2016 and December 31, 2019 to identify those with potentially acute and traumatic work-related injuries. We then used the initial work-related injury claim's "event date" to join enrollees to Inpatient, Outpatient, and Skilled Nursing Facility claims incurred within 90 days of the event date.

Injury case definition

We identified injuries resulting in hospitalizations, emergency department visits, and non-emergency department hospital/clinic visits. We used the CDC injury surveillance definition for emergency department visits, which identifies records with any injury diagnosis (ICD-10-CM S, T, O, and M codes) or external cause of injury code (V00-V99, W00-X58, X71-X83, X92-Y09, Y21-Y33, Y35-Y38) for an initial encounter, excluding subsequent encounters and sequelae[87,88]. External causes of injuries were classified by the External Cause of Injury Mortality Matrix using SAS code from the CDC[97].

Work-related ascertainment in claims data

We then filtered injury claims by two processes. For our first process, we used five payer-related variables that correspond to Medicare's instructions to providers for the coverage of work-related injuries and illnesses[55]. We assumed that any claim paid by workers' compensation would be work-related, as would claims denoting a step in the process of determining WC coverage for a claim[55]. Primary Payer: Claims paid by workers' compensation include a primary payer code and payment amount. Claim Value Code: Even without a direct WC payment, some claims have a conditional payment from Medicare while awaiting payment from a "higher priority WC plan", although it is not

indicated if WC ever reimbursed Medicare[55]. Claim-related Occurrence: Work-related events can be indicated on a claim, which alerts Medicare to potential WC involvement[55]. We used the claim-related occurrence code for "*Accident/employment related – The date of an accident relating to the patient's employment*", which also corresponds to a date for the event. Claim-related Condition: Work-related conditions that could possibly be covered by WC are also shown by the code for "*Employment related – Patient alleged that the medical condition causing this episode of care was due to environment/events resulting from employment*". Medicare non-payment reason: Claims may also be denied by Medicare due to workers' compensation. We considered any injury claim to be work-related if it contained at least one of the above codes.

For our second process, we identified claims that included at least one ICD-10-CM External Cause code for work-related injuries. The code list was obtained based on prior literature specifying any mechanism, activity, place, or status for a work-related or agricultural injury (see Appendix) [41,50]. We excluded several codes that seemed unlikely to involve older workers, such as codes involving the military. After combining claims meeting the above injury and work-related definitions, we limited the cohort to those reporting an "accident" date on the claim no earlier than 30 days before the hospital admission / outpatient visit. This was used to accurately classify healthcare claims as occurring before or after the event which led to the injury.

Demographic and clinical measures

We used the Medicare enrollment file for demographic variables from the year of the injury. We used continuous age and race/ethnicity codes (White, Black, Asian, Hispanic, North American Native, Other, Unknown. Rural and urban residence was grouped from counties using rural-urban continuum codes[89]. As a socioeconomic

indicator, we noted if an individual was enrolled in Medicaid, since enrollees may qualify by income for some healthcare benefits from their state Medicaid program[91,92]. Because co-morbidities may be a confounder of the relationship between the injury and healthcare utilization and costs, we calculated the Charlson Comorbidity Index, using a SAS macro from the National Cancer Institute (NCI)[117,118]. Patients with greater comorbidities could use a greater number of healthcare services, and therefore have higher costs before or after the injury. We also noted mortality in the 90-day post-injury period, admissions to the hospital, length of hospital stay, emergency department visits, operating room procedures, and intensive care unit services.

Cost and healthcare utilization measures

For claims occurring within 90 days pre- or post-injury, as well as the initial work-related injury claim, we calculated patient out-of-pocket costs as the sum of all coinsurance/deductible amounts on the claim. We assigned costs from the initial claim to the "post-injury" phase. We also considered the total claim cost from the initial claim, as well as the sum of all payers on the claim (patient coinsurance/deductible, Medicare payment, and payment from WC/other primary payers). Healthcare utilization, a measure of broad health care services, was defined as claims that indicated use of inpatient, outpatient, or skilled nursing facility services by enrollees during the study period.

Statistical analysis

We defined WC and non-WC cohorts based on whether any claim within 90 days of the work-related injury had a WC payment. We compared these groups by demographic measures and characteristics of the initial claim. We compared categorical

variables with chi-squared tests and continuous variables by their mean (t-test) or median by the non-parametric Wilcoxon rank sum test. We descriptively compared Outpatient, Inpatient, and Skilled Nursing Facility claims and patient costs in the 90 days pre and post-injury, comparing costs by claim type and in total.

To estimate the effect of WC coverage on claims billed to Medicare and enrollee out-of-pocket costs, we next compared pre/post-injury claims by service type (outpatient, inpatient, SNF) with difference-in-differences and time series analyses. We compared claims in the 90-days before and after the injury using GEE models with a Poisson distribution and log link, estimating the relative risk (RR) of incurring a claim after the injury, compared to before, and the relative risk ratio (RRR) between WC and non-WC groups. For the time series, we divided the study period into 24 weeks, with the injury occurring in week 13, allowing approximately 90 days of pre- and post-injury comparisons. We estimated the relative risk by week for incurring outpatient and inpatient claims. We adjusted models for age, race/ethnicity, sex, Medicare/Medicaid dual eligibility, rurality, initial claim type, total cost of the initial claim, the mechanism of injury, total number of injury diagnoses, and Charlson comorbidity score.

For out-of-pocket costs, we first ran another difference-in-differences analysis, using linear mixed models to compare mean costs before and after the injury, by WC status. We then ran a quantile regression model to estimate the 50^{th}, 75^{th}, and 90^{th} quantiles of outpatient and total out-of-pocket costs, at both 30 and 90 days post-injury. Similar to mean regression, quantile regression presents a non-linear method of analyzing healthcare costs, which are often highly skewed in nature[119,120]. We adjusted these models for age, race/ethnicity, sex, Medicare/Medicaid dual eligibility, rurality, the initial work-related injury claim type, total cost of the initial claim, mechanism

of injury, total number of injury diagnoses, and the Charlson comorbidity score. We also adjusted quantile regression models for 90-day pre-injury out-of-pocket costs. We performed all statistical analyses with SAS software version 9.4 (SAS Institute, Inc, Cary, NC, USA).

Results

From 2016-2019, we identified 13,039 Medicare fee-for-service enrollees with a work-related injury claim (**Figure 1**). The WC group accounted for 16.0% of the entire cohort. Compared to the non-WC group, the WC group was slightly younger, had a closer balance of male and female patients, a lower proportion of dual eligible enrollees, and less often resided in rural areas (**Table 1**). The non-WC group had slightly higher mean comorbidity scores and higher 90-day mortality than the WC group.

From the initial work-related injury claim, both groups had similar rates of emergency department services, but those with WC coverage had 40% higher operating room use and 20% lower ICU use than the non-WC group. Work-related injuries more often resulted in admission for the WC group, although both groups had a similar length of stay if admitted. Over half of injuries paid by WC were for falls, compared to 20.8% of the non-WC group. Costs of the initial claim, as totaled from all payers, were notably over 2.5X higher for the WC group.

Healthcare utilization and out-of-pocket costs overall increased following a work-related injury. These descriptive results are reported in **Table 2**. There were statistically significant increases in the risk of incurring an inpatient or outpatient claim post-injury, while patients with WC had a 12% reduction in the relative risk of incurring an outpatient claim post-injury (RRR 0.88, 95% CI 0.83, 0.93) (**Table 3**). Although difference-in-

differences estimates for inpatient and SNF claims were not statistically significant, the non-WC group saw a statistically significant increase in SNF claims after the injury.

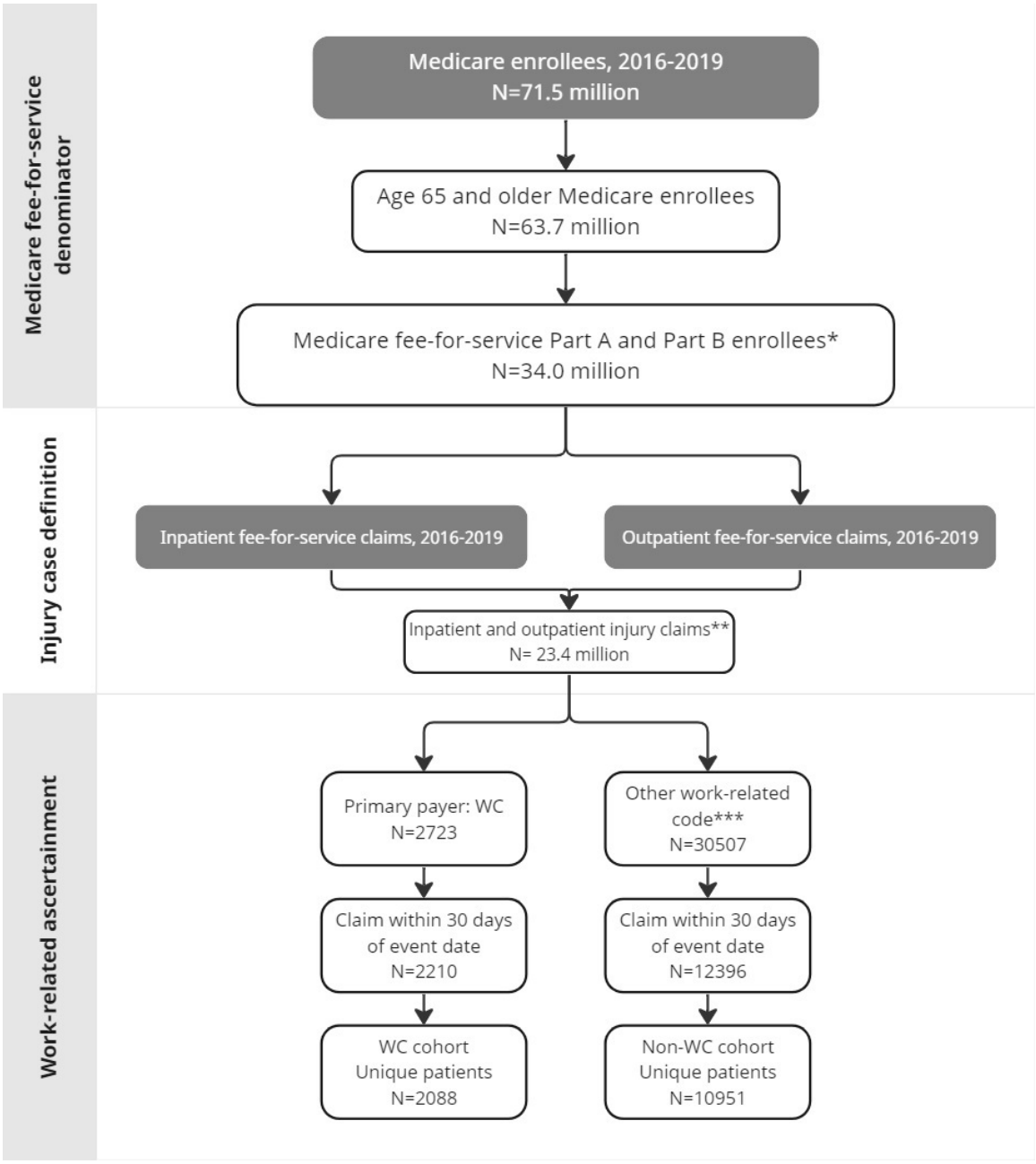
In the first week of the injury (Week 13), the risk of an outpatient visit increased for both the WC group (adjusted RR 1.87, 95% CI 1.41-2.48) and the non-WC group (RR 3.22, 95% CI 3.00-3.44) (**Figure 2**). The WC group had a lower RR of an outpatient visit compared to the non-WC group (RRR 0.58, 95% CI 0.47-0.72) (**Figure 2**). This difference persisted until four weeks after the injury (Week 17, RRR 0.80, 95% CI 0.63-1.00). From then on, the WC group's risk of an outpatient visit did not differ from before the injury, but the non-WC group had an elevated risk until the final week of the study period (Week 24 RR 1.32, 95% CI 1.22-1.43). Meanwhile, both groups saw a statistically significant increase in inpatient stays from Week 13 up to Week 17, while the trend persisted for the non-WC group from Week 13 to Week 19. The groups did not differ in their risk for an inpatient stay in the first week of the injury (RRR 1.66, 95% CI 0.64, 4.34) or afterward.

The difference-in-differences analysis for out-of-pocket costs saw increases in both groups after the injury (**Table 2**). For WC patients, the mean outpatient cost increased by $122 between the pre- and post-injury phase (95% CI 87, 157), but this increase was $94 less than the mean increase of the non-WC group (difference-in-differences -94, 95% CI -106, -81). Adding outpatient, inpatient, and SNF costs together, the WC group saw a pre/post mean increase of $452 (395, 509), which was $151 less than the mean increase in the non-WC group (difference-in-difference -151, 95% CI -177, -125).

Quantile regression revealed a concentration of out-of-pocket costs within 30 days of the injury, compared to the full 90 days (**Table 4**). Within 30 days of injury, the

non-WC group saw higher costs at the 50th, 75th, and 90th percentile compared to the WC group, both for outpatient and total (outpatient, inpatient, skilled nursing) claims. After adjusting for demographic and clinical characteristics, as well as pre-injury out-of-pocket costs, the cost difference for the WC group fell on a gradient, with 30-day outpatient costs $31 lower at the median (-31, 95% CI -25, -36), but $204 lower at the 90th percentile (-204, 9% CI -247, -161). For combined outpatient, inpatient, and SNF costs, the greatest differences were seen at 90 days in the 75th (-189, 95% CI -245, -134) and 90th (-601, 95% CI -805, -398) percentiles.

Figure 1. Medicare enrollees with a recent work-related injury, selection of WC and non-WC work-related injury cohorts.



*Continuous annual enrollment in Medicare fee-for-service Part A and Part B
**Injury claims: any Inpatient or Outpatient claim with ICD-10-CM diagnosis of injury (S, T, M, O codes), initial encounter, in any diagnosis position OR an ICD-10-CM external cause of injury, initial encounter.
***See methods: any work-related criteria identified in the absence of a WC primary payer code

Table 1. Medicare enrollees with work-related injuries from 2016-2019 (N=13039), demographic and clinical characteristics by WC payment status.

	WC group (N=2088)	Non-WC group (N=10951)	P value*
Enrollee characteristics	N (%)	N (%)	
Age, Mean (SD)	71.3 (5.4)	73.5 (6.8)	< .0001
Sex, N (%)			
Male	1157 (55.4)	8384 (76.6)	< .0001
Female	931 (44.6)	2567 (23.4)	
Race/ethnicity, N%)			
White	1835 (87.9)	10006 (91.4)	< .0001
Black	144 (6.9)	472 (4.3)	
Asian	23 (1.1)	54 (0.5)	
Hispanic	23 (1.1)	82 (0.8)	
North American Native	< 11 (<0.5)	47 (0.4)	
Other	25 (1.2)	91 (0.8))	
Unknown	< 42 (<2.0)	199 (1.8)	
Medicare / Medicaid dual eligible, N (%)	103 (4.9)	837 (7.8)	< .0001
Residence, N (%)			
Rural	445 (21.3)	4620 (42.9)	< .0001
Urban	1643 (78.7)	6160 (57.1)	
Year, N (%)			
2016	491 (23.5)	3132 (28.6)	< .0001
2017	533 (25.5)	2735 (25.0)	
2018	539 (25.8)	2590 (23.7)	
2019	525 (25.1)	2494 (22.8)	
Injury characteristics			
Initial encounter setting, N (%)			
Outpatient	1548 (74.1)	8562 (78.2)	< .0001
Inpatient	540 (25.9)	2389 (21.8)	
Services rendered, N (%)			
ER use, any	1817 (87.0)	9516 (86.9)	.8816
OR use, any	372 (17.8)	1533 (14.0)	< .0001
ICU use, any	140 (6.7)	1128 (10.3)	< .0001
Mechanism of injury, N (%)			
Fall	1058 (50.7)	2277 (20.8)	< .0001
Transportation	248 (11.9)	2782 (25.4)	
Machinery	33 (1.6)	2455 (22.4)	
Other mechanism	446 (21.4)	1790 (16.4)	
Unspecified/missing	303 (14.5)	1647 (15.0)	
Number of injuries on claim			
Mean (SD)	1.8 (1.6)	2.1 (2.1)	< .0001
Median (IQR)	1 (1,2)	1 (1,3)	< .0001

Inpatient length of stay (days)			
Mean (SD)	5.7 (6.7)	6.0 (6.9)	.3448
Median (IQR)	4.0 (2,6)	4.0 (2,7)	.7009
Injury date (days before claim)			
Mean (SD)	1.4 (4.0)	1.0 (3.0)	< .0001
Median (IQR)	0 (0,1)	0 (0,1)	.4742
Initial claim cost, $ (all payers)			
Mean (SD)	11390 (40717)	4291 (15533)	< .0001
Median (IQR)	1455 (657,7714)	571 (231,2171)	< .0001
Charlson Comorbidity Score			
Mean (SD)	0.8 (1.3)	1.1 (1.5)	< .0001
Median (IQR)	0 (0,1)	0 (0,2)	< .0001
Mortality within 90 days of injury, N (%)	38 (1.8)	417 (3.8)	<.0001

*Chi-square test (categorical variables), t-test (means), Wilcoxon rank-sum test (medians)

Table 2. Medicare claims by service type and enrollee costs (in USD) in the 90 days before and after a work-related injury, by WC payment status.

	WC group (N=2088)		Non-WC group (N=10951)	
	Pre-injury	Post-injury	Pre-injury	Post-injury
Enrollees with service type, N (%)				
Outpatient	927 (44.4)	1104 (52.9)	5801 (53.0)	7891 (72.1)
Inpatient	65 (3.1)	188 (9.0)	532 (4.9)	1543 (14.1)
SNF	< 11 (< 1.0)	44 (2.1)	84 (0.8)	902 (8.2)
Enrollee Outpatient costs, $				
Mean (SD)	106 (388)	226 (450)	166 (591)	492 (832)
Median (IQR)	0 (0,43)	105 (24,224)	0 (0,106)	203 (84,523)
Total enrollee costs, $				
Mean (SD)	139 (459)	606 (917)	239 (775)	1096 (1985)
Median (IQR)	0 (0,49)	190 (75,1288)	0 (0,125)	367 (123,1438)

*Total of outpatient, inpatient, and SNF claim costs

Table 3. Difference-in-differences analysis of Medicare claims and out-of-pocket costs (in USD), by workers' compensation status.

Medicare claims billed by service type*

	WC group (N=2088)		Non-WC group (N=10951)		
Claim category	**Pre/Post Injury RR**	**95% CI**	**Pre/Post Injury RR**	**95% CI**	**RRR (95% CI)**
Outpatient	1.24	1.33, 1.36	1.36	1.33, 1.38	0.88 (0.83, 0.93)
Inpatient	1.86	1.31, 2.68	2.68	2.44, 2.94	1.06 (0.80, 1.40)
SNF	2.03	0.51, 8.00	10.61	8.47, 13.29	1.32 (0.41, 4.24)

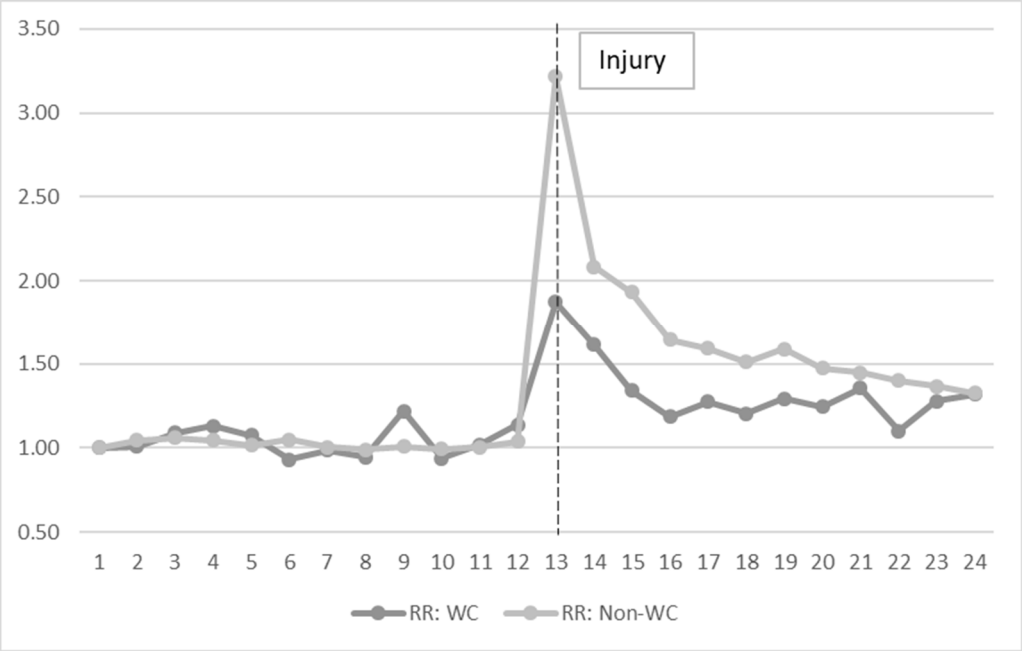
Medicare enrollee costs (total deductibles/coinsurance)*

	WC group (N=2088)			Non-WC group (N=10951)			
Enrollee cost category ($)	Pre-injury (95% CI)	Post-injury (95% CI)	Diff (95% CI)	Pre-injury (95% CI)	Post-injury (95% CI)	Diff (95% CI)	D-I-D (95% CI)
Outpatient costs, $	122 (87, 157)	243 (208, 278)	120 (93, 147)	121 (91, 151)	334 (305, 364)	214 (199, 228)	-94 (-106, -81)
Total costs**, $	337 (275, 398)	789 (727, 850)	452 (395, 509)	365 (315, 416)	968 (917, 1019)	603 (572, 634)	-151 (-177, -125)

*Models adjusted for age, race/ethnicity, sex, Medicare/Medicaid dual eligibility, rural residence, Charlson comorbidity index, the initial work-related injury claim type, initial claim year, total cost of the initial claim, and the initial claim's mechanism of injury and total number of injury diagnoses.
**Total of outpatient, inpatient, and SNF claim costs

Figure 2. Time series analysis for relative risk (RR) of Medicare outpatient and inpatient claims following a work-related injury, by workers' compensation status.

A. Outpatient visits



B. Inpatient admissions

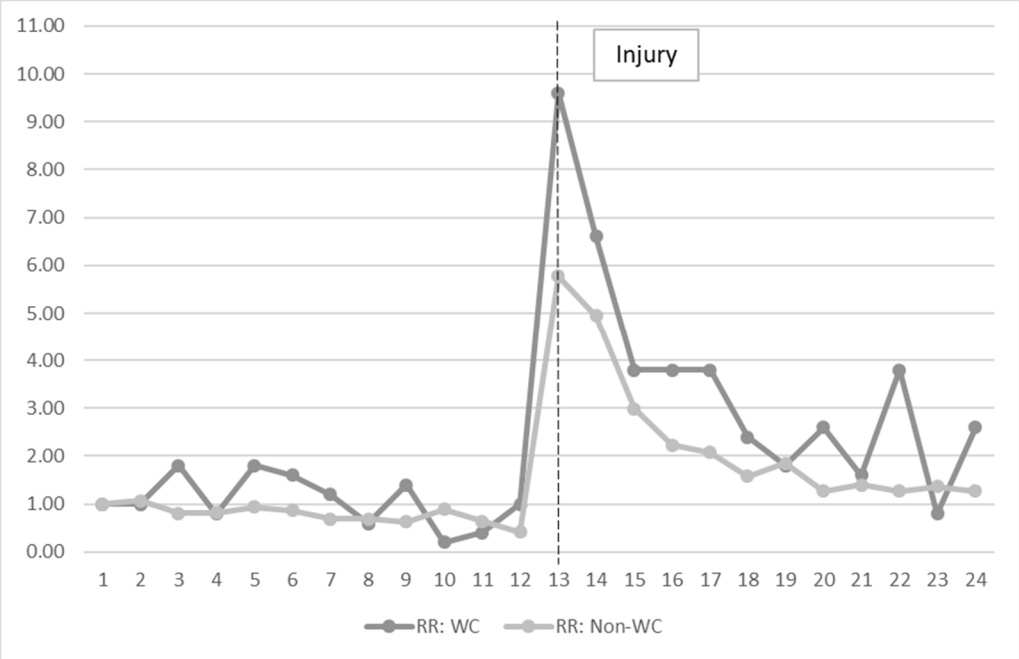


Table 4. Quantile regression estimates of the effect of WC status on Medicare enrollee out-of-pocket costs (in USD) after a work-related injury.

	Enrollee cost percentile					
	50th	95% CI	75th	95% CI	90th	95% CI
Outpatient costs, $						
30-day						
WC	72	59, 86	170	142, 197	340	245, 435
Non-WC	147	142, 151	343	331, 356	863	822, 905
Diff (unadjusted)	-74	-84, -65	-174	-189, -159	-523	-577, -470
Diff (adjusted)*	-31	-36, -25	-69	-82, -57	-204	-247, -161
90-day						
WC	105	89, 120	224	180, 269	538	427, 649
Non-WC	203	198, 209	523	503, 542	1287	1239, 1336
Diff (unadjusted)	-99	-108, -89	-298	-323, -273	-750	-812, -687
Diff (adjusted)*	-50	-60, -40	-126	-147, -104	-337	-401, -272
Total cost, $**	**50th**	**95% CI**	**75th**	**95% CI**	**90th**	**95% CI**
30-day						
WC	141	119, 163	1065	871, 1260	1352	1272, 1431
Non-WC	230	222, 239	1316	1296, 1336	1777	1740, 1814
Diff (unadjusted)	-89	-103, -75	-251	-425, -76	-425	-467, -383
Diff (adjusted)*	-43	-50, -36	-102	-134, -70	-322	-451, -193
90-day						
WC	190	150, 231	1288	1238, 1338	1432	1273, 1591
Non-WC	367	349, 385	1438	1419, 1458	2465	2388, 2543
Diff (unadjusted)	-177	-199, -154	-150	-181, -119	-1033	-1115, -951
Diff (adjusted)*	-70	-85, -54	-189	-245, -134	-601	-805, -398

*Models adjusted for age, race/ethnicity, sex, Medicare/Medicaid dual eligibility, rural residence, Charlson comorbidity index, the initial work-related injury claim type, initial claim year, total cost of the initial claim, and the initial claim's mechanism of injury and total number of injury diagnoses.
**Total enrollee Inpatient, Outpatient, and SNF costs

Discussion

As occupational injury costs shift from workers' compensation to public insurance like Medicare, older adults may face a higher burden of healthcare costs[11,111]. In this study, we identified Medicare fee-for-service enrollees with a recent work-related injury and compared their healthcare utilization through Medicare and corresponding out-of-pocket costs. Regardless of WC status, we found patients to have a greater number of

Medicare inpatient and outpatient claims following a work-related injury, compared to before. While a work-related injury was associated with higher out-of-pocket costs for patients, those with WC had smaller increases in outpatient and total out-of-pocket costs following the injury than those without WC.

Medicare pays secondary to workers' compensation, and increases in Medicare inpatient, outpatient, and skilled nursing claims after an injury suggest that WC coverage was insufficient for patients' medical care. This echoes previous research among a broader age group of working adults, which estimates those with paid WC claims to incur 41% higher outpatient costs and 32% higher inpatient costs on their group health insurance in the immediate 2-3 months after an injury[110]. If WC claims were unpaid (i.e. zero cost), the same study estimated this would result in 59% higher outpatient costs and 168% higher inpatient costs[110]. Similarly, we found mean outpatient costs to increase by 100% and 250% in the WC and non-WC groups, respectively. Total out-of-pocket costs increased by over 100% for our WC group, while these costs were 250% higher in the non-WC group. Similar to past studies with group health insurance (GHI) claims, our results seem to confirm that excess costs of work-related injuries are found in Medicare, and these costs are attenuated, at least in part, when workers' compensation is involved[16].

There may be several explanations for why the WC group had fewer Medicare claims and associated out-of-pocket costs. Workers' compensation coverage may lower the patient responsibility on claims where WC is a payer. It is also possible that when WC was confirmed as a payer, some providers did not submit claims to Medicare. Providers are instructed to bill Medicare with a zero cost claim even when billing WC insurance, but our results could suggest this routine is not always followed[55]. However,

even with the gap in Medicare inpatient and outpatient claims, we can be more certain of the difference in *patient* costs, since any claim that went to WC would not be expected to have costs for the patient.

We complemented our difference-in-differences analysis with quantile regression, targeting higher cost percentiles. Of the services examined, quantile regression identified 10% of those without WC owing nearly $2500 or more within 90 days of the injury. After adjustment, the WC group owed $600 less than the non-WC group at this percentile. We also found the 90th percentile group to be slightly older, more likely to live in rural areas (57% vs 39%), and have a higher rate of agricultural injuries (19% vs 10%) than those in the lower percentiles. This reflects a broader pattern in healthcare literature that a smaller, medically vulnerable group of patients can often incur the highest burden of healthcare costs[15,16]. For the work-related injury cohort, this vulnerability may come from age-related factors, difficulty obtaining WC coverage, and the possibly severe nature of agricultural injuries[11,12,61].

Strengths and Limitations

A strength of our study was our precise estimate of enrollee costs, using exact dollar amounts from Medicare administrative claims. With the individual identifier in Medicare data, we were able to explore longitudinal costs after the injury. This allowed for the difference-in-differences analysis, a strong, quasi-experimental method often used for causal inference in economic studies[121]. This allowed us to identify "excess" costs beyond patients' typical healthcare use. Our study also uniquely leveraged the date of the "accident" or event date from Medicare claims. We often saw a spike in claims just a few days before the first work-related injury claim, and this event date helped us to classify these costs to the post-injury phase.

Our study also benefits from a varied definition of work-related injuries, and we can test the sensitivity of our methods within subgroups. Using the more certain work-related codes that Medicare instructs providers to use, we still find an effect of WC on patient costs[55]. While the WC group (N=2088) has $452 (95% CI 395, 509) higher mean costs after injury, this is still $87 less than the $603 increase (95% CI 572, 634) in this non-WC subgroup, whose injuries were billed to Medicare as "employment-related" (N=1742).

Our study also has limitations, first that these results are only generalizable to those enrolled in fee-for-service Medicare, age 65 and older, with both Part A and B coverage. Those with Medicare Advantage or only enrolled in Medicare Part A could utilize their insurance differently with regard to work-related injuries. We also focused mostly on claims from hospitals, and most injuries were first seen in the ED. We likely missed many minor injuries seen in offices or clinic settings. With only a 90-day window, we also could not estimate long-term effects of work-related injuries on enrollee claims or cost. At the end of our 90-day window, we still saw an elevated number of claims on a weekly basis, relative to before the injury. Future research may seek to examine a broader scope of healthcare services or estimate long-term costs of injuries.

Our definition of cost is limited in that we cannot be certain how this financial liability impacts Medicare enrollees. We did not cover all claim types, possibly underestimating costs. We also cannot estimate lost wages, which can be substantial[61]. We also cannot be sure if patients ended up owing these costs since we have no indicator for supplemental insurance, such as Medi-Gap policies, which can help Medicare enrollees with out-of-pocket costs[122]. Lastly, we cannot know if these costs were affordable to patients. An estimated 12% of older Medicare enrollees have

problems paying their medical bills injury, but we had only a limited socioeconomic indicator for dual enrollees[15]. Furthermore, financial hardship can also be greater after a traumatic injury, and working age adults are more likely to go into medical debt or bankruptcy[116].

Conclusion

In this study, we found evidence to suggest that workers' compensation does not adequately control financial liability for older adults on Medicare. Overall, work-related injuries present a significant cost burden for Medicare enrollees, even while they face many serious health outcomes. These excess costs seem relatively higher than past studies with younger age groups. Workers' compensation may have some protective effect against the high combined costs of outpatient, inpatient, and skilled nursing care. With occupational injury costs shifting from workers' compensation to personal health insurance, older adults may stand to incur some of the highest costs of work-related injuries through Medicare deductibles and coinsurance. Future research is needed to ensure greater access to workers' compensation insurance for older adults, as well as to understand the long-term effects of a work-related injury on patient costs and health outcomes in Medicare.

Chapter 5: Manuscript 3

Job lock, work status, and the incidence of occupational injury among older workers in the Health and Retirement Study

Abstract

Background

Job lock is a perceived retirement barrier related to a reliance on employer benefits and has been associated with a variety of negative health outcomes. We used longitudinal data from the Health and Retirement Study to explore the effects of job lock on occupational injuries among older workers. We hypothesized that workers reporting job lock would also have a higher incidence of occupational injuries reported on the survey.

Methods

We used 2010-2018 data from the Health and Retirement Study to identify two age-based cohorts of workers – those aged 55-64 and age 65 and older. We then used repeated measures negative binomial regression models to estimate the longitudinal effect of job lock on work-related injuries in these two cohorts, hypothesizing that job lock would increase the incidence of work-related injuries. We also explored effect modification from work status and self-employment.

Results

Job lock was found to increase the incidence rate of occupational injuries in the age 55-64 cohort (IRR 1.59, 95% CI 1.25-2.03), but not in the age 65 and older cohort (IRR 0.87, 95% CI 0.54-1.39). In the age 55-64 cohort, self-employed or "partly-retired" workers did not show such an effect, but these effects were present in full-time (IRR

1.69, 95% CI 1.28-2.25) and part-time workers (IRR 1.89, 95% CI 1.06-3.37), as well as workers who were not self-employed (IRR 1.68, 95% CI 1.29-2.19).

Conclusion

Prior to age 65, job lock appears to effect the occupational injury risk for older workers, but those who are self-employed or "partly retired" may experience job lock differently on account of greater control over their work environment. If stratified on other aspects of the work arrangement, job lock may be a useful indicator of work-related injury risk for some older adults.

Introduction

Workers in the US are retiring later, possibly the result of decreased availability of retirement benefits and an increase in the Social Security retirement age[2]. Even as workers in the US become eligible for Medicare or Social Security, over 10 million older adults continue to work past the age of 65, with at least 60% working full time[123,124]. A need for income and employer-provided health insurance have been suggested as reasons that older workers remain in full-time work, creating a "job lock" situation[3]. This raises concern that older workers, particularly those in physically demanding jobs, may continue to work to receive these benefits, even as they are less fit to do so, placing them at greater risk of occupational injury[69,70].

Job lock has often been conceptualized as workers' perception that they cannot leave their job or retire out of need for income or employer-provided health insurance[3,69,70]. Workers in job lock also tend to have greater work limitations, as well as other health conditions that may place them at greater risk of injury, although the longitudinal risk of occupational injury from job lock has not yet been established[69,70]. However, perceived job immobility has been associated with lower life satisfaction and reduced post-retirement wellbeing, as well as insomnia among older workers, suggesting that job lock can have negative health consequences[3,71,72].

As a perceived retirement barrier, past studies have not considered job lock in the context of work arrangements commonly found among older adults. While many older adults continue to work full time, others may seek forms of partial retirement, such as reduced hours with a new or existing employer, or becoming self-employed[4,8]. Full time work status may increase the risk of an occupational injury or illness, while part time work may be a protective factor[66,74]. Self-employment has been suggested as a sign of precarious work or a protective factor against occupational injury[125,126]. These

arrangements, which may directly impact income or eligibility for employer health benefits, could confound associations or modify the effect between job lock and health outcomes among older adults.

Age creates another layer to explore in job lock, particularly beginning at age 65 when most adults in the US become eligible for Medicare, as well as at age 66-67 when many reach the Social Security retirement age[20,127]. These social programs could alleviate job lock to some extent, although workers may still perceive the need to work. Medicare Part A (hospital insurance) is free to most adults when they turn 65, although Medicare Part B (medical insurance) has premiums that could discourage some from enrolling and instead keep their employer-provided health coverage[127]. Social Security, when available, is dependent on past earnings and only covers a fraction of the income for most older households[128,129]. Although complex, the sum of these sources could potentially shift the nature of job lock past the age of 65, and may therefore impact the effect of job lock on occupational injuries.

As older adults weigh many financial, employment, and health-related decisions, the economic determinants of health become important to consider in terms of workplace safety. Job lock, a self-reported retirement barrier and possible indicator of job immobility among older workers, could be a work-related stressor. Given its presumed connection to the work arrangement, job lock could also differentially impact workers' risk of injury depending on full-time/part-time status or self-employment. In this study, we used longitudinal panel data from the Health and Retirement Study to study the effect of job lock on work-related injury in a group of Medicare-aged workers in the US from 2010-2018. We hypothesized that workers in job lock would have an increased incidence rate of occupational injuries compared to workers who did not report job lock. We also explored the modifying effects of job status, including full, part-time, or partly-

retired work, as well as self-employment, on the relationship between job lock and occupational injury.

Methods

Data source

The data for this study are from the Health and Retirement Study (HRS), a nationally representative survey of the US population age 50 and older[130]. As a biennial longitudinal survey, the HRS samples households with at least one member who is age 50 or older, oversampling African American and Hispanic respondents[130]. The HRS (Health and Retirement Study) is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan. Participants are recruited with a household screening interview, and upon recruitment complete a baseline interview. Respondents are interviewed every two years, receiving the HRS Core interview which includes a wide range of questions covering topics such as health, family structure, employment, retirement, and finances[131]. The HRS has a relatively high response rate, reporting an 87.1% response rate overall from the 2014 wave[131].

After completing the core interview in each wave, half of participants are given a psychosocial "Leave-Behind" questionnaire to collect further information beyond what was covered in the interview. In the subsequent study wave, the remaining half of participants will receive the Leave Behind questionnaire. Essentially, while the HRS Core interview is conducted every two years, respondents receive this questionnaire every four years. This study used the publicly available 2010-2020 RAND HRS longitudinal survey file, which includes cleaned measures from the HRS Core survey for ease-of-use[132]. The job lock question was taken from the separate HRS psychosocial Leave Behind questionnaire [130].

Study design

For this study we selected two separate age-based cohorts using an open cohort design. The two respective cohorts were based on workers who were aged 55-64 and age 65 and older at the time of the survey. We selected those who were working for pay during the 2010-2018 HRS waves and also completed the job lock questionnaire from the Leave Behind survey. Since only half of respondents were given the job lock questionnaire in any given wave, respondents were included in either of the cohorts in the first wave in which they 1) met the cohort's age criteria, 2) were currently working for pay, and 3) responded to the job lock questions. Since for any given individual the survey is administered every two years, but the job lock question is given every four years, we carried forward the job lock response to fill in the missing wave before the question was asked again.

Once selected, work-related injuries were compared to the job lock exposures longitudinally, based on the response to a work-related injury question in the subsequent wave (e.g. 2010 job lock compared to 2012 work-related injury question). We used the 2020 HRS wave only for the work-related injury outcome. While respondents had to be working at the time of the survey in order to be asked the job lock exposure questions, they did not need to be working in order to receive the work-related injury question, since the question was asked regarding the prior two years.

Study variables

Work-related injuries. Respondent were asked if they had "an injury at work that required special medical attention or treatment or interfered with work activities" during the past two years, followed by a question asking the number of injuries[130]. We kept the question as a count variable for the outcome. We used the same variable from previous waves as a measure of previous work-related injuries.

Job Lock. Participants were asked "Right now, would you like to leave work altogether, but plan to keep working because…" followed by the prompts "You need the money?" and "You need health insurance?" with the option to respond "Yes" or "No" to each prompt. Effect Modifiers. As potential effect modifiers, we considered the response for job status, either full-time, part-time, or partly-retired, which was asked regarding a respondent's current job at the time of the survey. We also used a separate question asking whether the respondent was self-employed.

We considered several other work-related measures as potential confounders, also based on a respondent's current job at the time of the survey. This included hourly wages, weekly hours, and physical job demands. Respondents were asked to respond to the statement, "My job requires lots of physical effort", on a scale of "None or almost none of the time" up to "All or almost all of the time". We used Census occupations from the survey and grouped them further based on 2018 Census definitions[133]. We also combined three health insurance variables to create a mutually exclusive variable of health insurance status (Medicare, Medicare and EPHI, EPHI only, other insurance). For demographic variables, we considered continuous age and categories provided by the survey for gender (female or male), race (White/Caucasian, Black/African American, Other) and ethnicity (Hispanic, not Hispanic). We recoded marital status into three categories (Married/partnered, separated/divorced/widowed, never married). We grouped education into four categories (No degree/GED, High school, Some college, College or above). As a measure of comorbidities, we created a count variable based on the self-reported presence of any of nine conditions at the time of the survey (cancer, high blood pressure, diabetes, sleep problems, arthritis, stroke, heart condition, lung conditions, psychiatric conditions).

Statistical analysis

As suggested by previous studies, we first assessed the effects of financial and health insurance job lock separately[3,71]. We also created a third category for those who uniquely responded "Yes" to both job lock questions (job lock because of financial need, or health insurance) in any given wave, to assess any unique or elevated risks in this group. We descriptively compared the age 55-64 and age 65+ cohorts by demographic and occupational characteristics, job lock questions, and injuries.

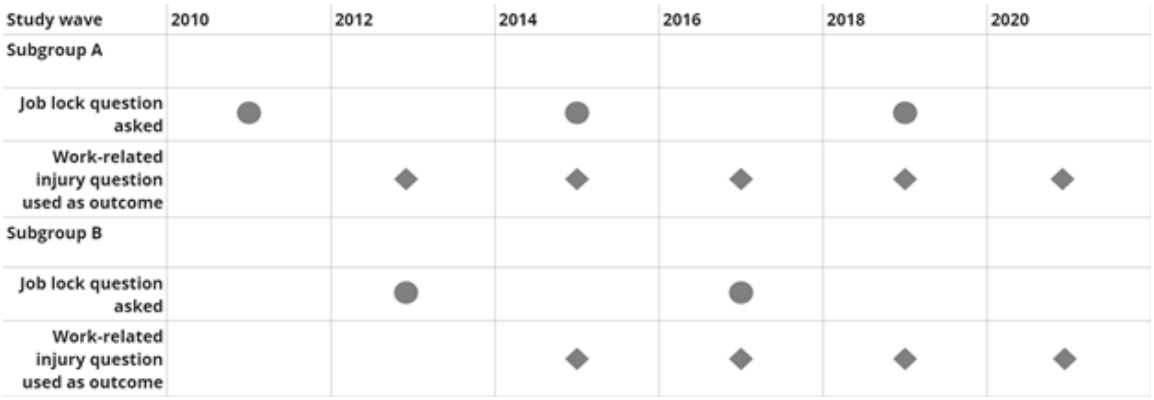
We then calculated a work-related injury incidence rate, using two approaches. First, for each study wave we estimated the total number of work-related injuries per 100 workers for each cohort, by work status (full, part-time, partly retired). We then used two variables to calculate a full-time equivalent (FTE) rate of injuries. For this denominator, we took each respondent's reported number of hours in a typical work week, multiplied by their reported number of weeks worked in a year, and summed these hours across all respondents in the group. This total was then divided by 2080 annual hours (40 hours x 52 weeks) to calculate the FTE denominator for the group[134]. We then reported the number of work-related injuries per 100 FTE, by age and work status.

To model the longitudinal effect of job lock on work-related injuries, we first developed directed acyclic graphs (DAGs) to draw out hypothesized associations between job lock and work-related injuries, as well as to assess potential confounders[135]. This informed us of several potential confounders to adjust for in our models. For descriptive purposes, we also performed bivariate comparisons of all potential confounders included in the DAGs, with the binary outcome of injury, using chi-squared tests.

We modeled the count of work-related injuries reported per wave, using generalized estimating equations (GEE) with a negative binomial distribution, accounting

for within-subject correlation. We ran separate models for the age 55-64 and age 65+ study cohorts. Models were adjusted for age, gender, race, ethnicity, occupation, previous work-related injuries, physical job, wages, tenure, weekly hours, and marital status. We separately assessed effect modification from work status and self-employment, reporting both unstratified and stratified incidence rate ratios (IRR) for the effect of job lock on work-related injuries. We used multiple imputation by chained equations to impute values for all variables with missing data, with ten imputations, in order to consider possible bias in prediction from variables missing at random. We also ran sensitivity analyses to consider whether a selection bias may be present, in which workers age 55-64 may have been less likely to keep working after 65 based on job lock. We conducted all analyses using Stata/MP 17[136].

Figure 1. Timing of job lock question administration and subsequent comparison to work-related injury question in future waves.



*Subgroups: respondents received the job lock question every other study wave, on the Leave Behind questionnaire. Half of respondents received the Leave Behind questionnaire in 2010, 2014, and 2018 (subgroup A), while the other half received the questionnaire in 2012 and 2016. The work-related injury question was asked in each study wave.

Results

From the 2010-2018 HRS survey waves, we identified 4475 respondents age 55-64 who were working and responded to the job lock question, out of 12951 respondents in this age group (Cohort 1). We separately identified 1957 respondents age 65 and older who were working and responded to the job lock question, out of 15700 respondents in this age group (Cohort 2). Descriptively, we noted several differences between these cohorts at baseline inclusion (**Table 1**). Cohort 1 had a higher proportion of Black/African American respondents for race and a higher proportion of Hispanic respondents. Cohort 1, perhaps on account of age, had a lower proportion of respondents with two or more chronic conditions, compared to Cohort 2 (42.8% vs 63.5%). Nearly half (44.9%) of Cohort 2 reported being "partly retired", whereas only 8.4% of Cohort 1 reported this status. Work-related injuries were more common in Cohort 1 than in Cohort 2, both for having a previous wave injury at baseline (5.0% vs 3.0%) and injuries in follow up (9.5% vs 6.3%). Job lock was relatively common in both cohorts, with well over half of respondents reporting some form of job lock at baseline. The average rate of work-related injuries by wave, per 100 workers, as well as per 100 FTE, was approximately 50% higher among full-time workers aged 55-64, compared to full-time workers aged 65 and older (**Figure 2**). Work-related injury rates were similar between the cohorts for part-time workers, while partly-retired workers had rates 20-30% higher in the age 55-64 cohort than the 65+ cohort. Part-time and partly-retired worked notably had work-related injury rates that were 2-3 times higher after accounting for annual hours worked in the denominator, while the rates were similar for either denominator for full-time workers.

By age cohort, the overall physical demand reported for work decreased from 36.6% to 28.5% between age groups (**Table 2**). Several occupations also saw a

reduction in the age 65 and older cohort, such as construction (4.2% vs 2.6%), production (5.8% vs 2.9%), while others were similar like the service industry (19.2% vs 20.4%), or even saw a slight increase such as transportation/material moving (6.3% vs 7.1%). Occupation and job physicality were among the baseline exposures associated with having an injury in follow up, as well as for wages, previous injuries, and all three of the job lock measures. Cohort 1 (55-64 year olds) saw a notably higher proportion of injured workers in service occupations (12.3% vs 4.9%), office and administrative support (6.4% vs 3.5%), and professional/related occupations (9.4% vs 4.8%). Meanwhile, Cohort 1 seemed to have a lower proportion of injured workers in the management, business, and financial category (4.3% vs 7.2%) than cohort 2.

Effect estimates for job lock on the incidence rate of work-related injuries are presented in Table 3. Adjusting for potential confounders, those aged 55-64 had a higher incidence rate of work-related injuries if they reported job lock in a previous wave. These results were similar whether the respondent reported job lock for financial reasons (IRR 1.62, 95% CI 1.17-2.24), health insurance reasons (IRR 1.64, 95% CI 1.23-2.19), or both of these reasons (IRR 1.52, 95% CI 1.21-1.92). Upon repeating the analysis for the age 65+ cohort, a significant association was not found between job lock and the risk of work-related injuries.

Stratum-specific estimates for effect modifiers are also reported in Table 3. For the age 55-64 cohort, employment status appeared to modify the effect of job lock on the risk of work-related injuries. While full-time 55-64 year-old workers, as well as those who were not self-employed, had a higher risk of work-related injuries if they reported either or both types of job lock, job lock did not have a significant association with work-related injuries for partly-retired or self-employed workers. Part-time workers in this age group (55-64 years old), if reporting job lock due to both financial and health insurance

reasons, or just health insurance reasons, also had a higher incidence rate of work-related injuries compared to those who did not report job lock in this regard. For the age 65 and older cohort, partly-retired workers notably had a higher incidence of injuries if they reported financial job lock (IRR 2.71, 95% CI 1.22-6.02).

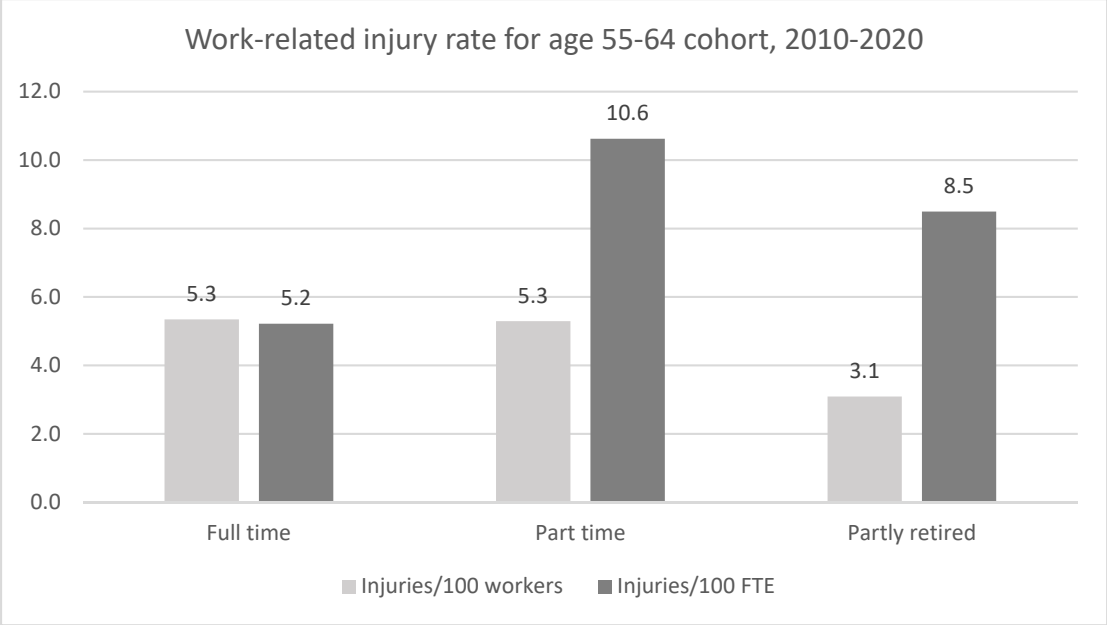
From our sensitivity analysis, to consider whether a selection bias may be present back on job lock, we found similar rates of continuing to work past the age of 65, whether not someone reported job lock before age 65. For example, in the 2010 wave, of those aged 61-64, 36.8% of those who reported job lock were still working in 2014 (the time of the next job lock questionnaire), compared to 33.4% of those who did not report job lock (chi-square (1) = 1.34; P=0.246). While a number of workers retired before age 65, this selection into the age 65+ cohort did not appear to differ by job lock status.

Table 1. Age-based cohorts of respondents to the job lock questions on the HRS Psychosocial and Lifestyle Questionnaire, from 2010-2018.

	Cohort 1: Age 55-64		Cohort 2: Age 65+	
	N	%	N	%
Total respondents	4475	100.0%	1957	100.0%
Gender				
Male	1973	44.1%	988	50.5%
Female	2502	55.9%	969	49.5%
Race				
White/Caucasian	3142	70.5%	1599	81.7%
Black/African American	843	18.9%	253	12.9%
Other	46	10.5%	105	5.4%
Ethnicity				
Hispanic	639	14.3%	155	7.9%
Not Hispanic	3829	85.7%	1801	92.1%
Marital status				
Married/partnered	3194	71.4%	1359	69.4%
Separated/divorced/widowed	980	21.9%	536	27.4%
Never married	299	6.7%	62	3.2%
Education				
No degree/GED	560	12.5%	268	13.7%
HS	1989	44.5%	913	46.7%
Some college	419	9.4%	109	5.6%
College or above	1507	33.7%	667	34.1%
Number of chronic conditions				
0	1125	25.1%	248	12.7%
1	1437	32.1%	466	23.8%
2	1096	24.5%	586	29.9%
3+	817	18.3%	657	33.6%
Work status				
Full	3472	77.6%	888	45.4%
Part time	626	14.0%	190	9.7%
Partly retired	377	8.4%	879	44.9%
Self employed				
Yes	686	15.3%	508	26.0%
No	3788	84.7%	1444	74.0%
Job tenure				
Over 5 years	2896	64.7%	1312	67.1%
Under 5 years	1579	35.3%	644	32.9%
Health insurance				
Medicare + employer health insurance	8	0.2%	480	24.6%

Medicare only	57	1.3%	1243	63.6%
Employer health insurance only	2679	60.0%	171	8.8%
Other insurance	1725	38.6%	61	3.1%
Hourly wage				
>= $15	3028	69.7%	1151	60.3%
< $15	1316	30.3%	758	39.7%
Weekly hours				
Under 30	3790	84.7%	1134	58.0%
30 or above	685	15.3%	823	42.0%
Physical job				
All/almost all the time	922	20.9%	295	15.5%
Most of the time	696	15.8%	248	13.0%
Some of the time	1353	30.6%	617	32.4%
None/almost none of the time	1445	32.7%	743	39.1%
Previous work-related injury				
Yes	223	5.0%	58	3.0%
No	4252	95.0%	1899	97.0%
Work-related injuries in follow up				
0	4051	90.5%	1834	93.7%
1	306	6.8%	92	4.7%
2	82	1.8%	22	1.1%
3+	36	0.8%	9	0.5%
Employed waves (to assess exposures)				
1 wave	3242	72.4%	1464	74.8%
2 waves	1147	25.6%	415	21.2%
3+ waves	86	2.0%	78	4.0%
Job lock (earliest response)				
Financial reasons				
Yes	3561	80.3%	1225	63.1%
No	875	19.7%	715	36.9%
Health insurance				
Yes	3122	73.7%	829	47.1%
No	1113	26.3%	930	52.9%
Both				
Yes	3016	71.9%	802	41.0%
No	1180	28.1%	1155	59.0%

Figure 2. Work-related injury rate by full (FT), part time (PT), and partly-retired status, 2010-2020.



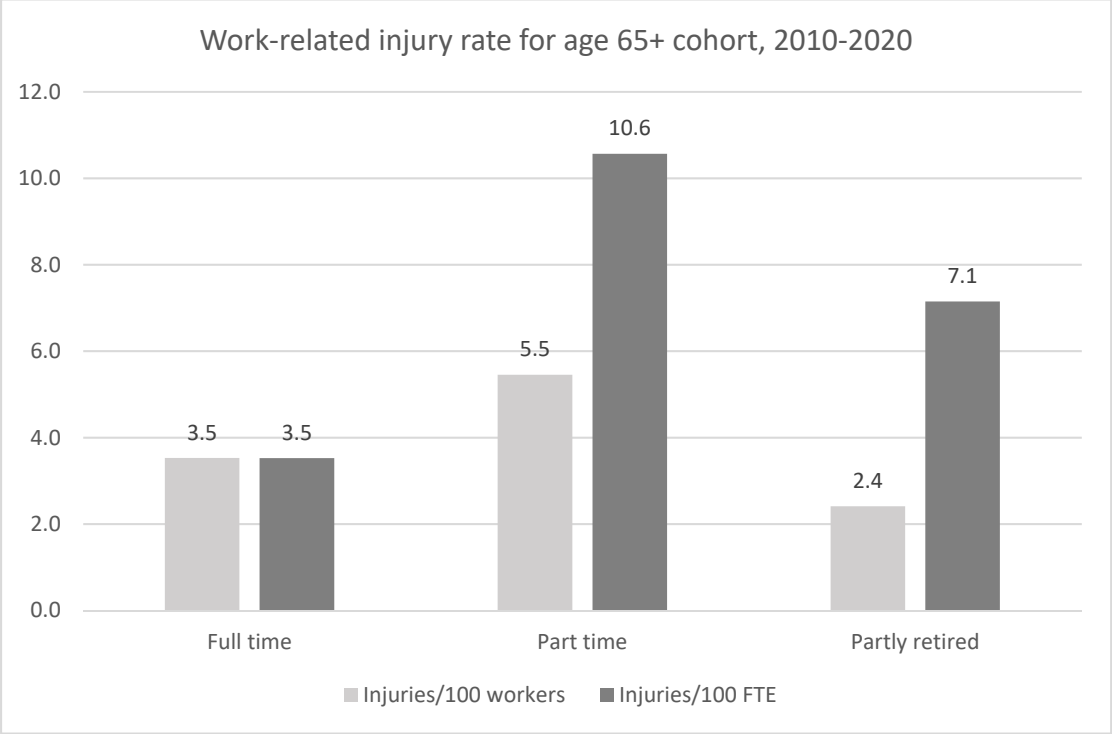


Table 2. Association between baseline occupational and job lock exposures and work-related injuries during follow up waves.

	Cohort 1: Age 55-64			Cohort 2: Age 65 plus		
Baseline exposures	Total	% injured	P-value	Total	% injured	P-value
Work status						
Full	3472	9.7	0.620	888	5.9	0.699
Part time	626	9.1		190	7.4	
Partly retired	377	8.2		879	6.5	
Self-employed						
Yes	686	9.8	0.778	583	7.9	0.079
No	3788	9.4		1555	5.7	
Weekly hours						
Under 30	685	7.9	0.122	1134	7.0	0.145
30 or above	3790	9.8		823	5.4	
Wage						
>= $15	3028	8.6	**0.005**	1151	5.0	**.004**
< $15	1316	11.3		758	8.2	
Physical job						
All/almost all the time	922	14.6	**< .001**	295	11.5	**< .001**
Most of the time	696	14.4		248	12.1	
Some of the time	1353	8.1		617	6.2	
None/almost none of the time	1445	5.3		743	2.8	
Occupational category						
Management, business, financial	715	4.3	**< .001**	265	7.2	**< .001**
Professional/related	920	9.4		393	4.8	
Service	846	12.3		392	4.9	
Sales and related	363	8.0		278	6.1	
Office & admin support	739	6.4		313	3.5	
Construction/extraction	186	17.2		50	12.0	
Installation/maintenance/repair	130	18.5		41	19.5	
Production occupations*	255	12.9		55	10.9	
Transportation/material moving	277	11.9		137	10.2	
Job lock (financial)						
Yes	3956	9.7	**< .001**	1225	7.2	**.034**
No	1009	6		715	4.8	
Job lock (health insurance)						
Yes	3108	10.0	**< .001**	829	8.1	**.007**
No	1201	5.7		930	5.0	
Job lock (both)						
Yes	3016	10.5	**< .001**	802	8.1	**.006**
No	1459	7.3		1155	5.0	

Previous injury							
	Yes	223	61.4	**< .001**	58	51.7	**< .001**
	No	4252	6.8		1899	4.9	

Table 3. Longitudinal effect of job lock on work-related injuries, with effect modification of work arrangements.

	Financial job lock		**Health insurance job lock**		**Both**	
	IRR	95% CI	IRR	95% CI	IRR	95% CI
Cohort 1: age 55-64						
Overall	**1.62**	**1.17 - 2.24**	**1.64**	**1.23 - 2.19**	**1.52**	**1.21 - 1.92**
Stratified by Work Status						
Self employed	1.21	0.63 - 2.33	1.45	0.78 - 2.71	1.20	0.69 - 2.08
Not self employed	**1.76**	**1.21 - 2.58**	**1.70**	**1.22 - 2.35**	**1.59**	**1.24 - 2.06**
Full time	**1.60**	**1.10 - 2.33**	**1.74**	**1.24 - 2.46**	**1.56**	**1.19 - 2.04**
Part time	2.11	0.82 - 5.43	**2.24**	**1.06 - 4.71**	**1.97**	**1.13 - 3.43**
Partly retired	1.33	0.55 - 3.19	0.75	0.33 - 1.70	0.72	0.33 - 1.59
Cohort 2: age 65+						
Overall	1.22	0.79 - 1.88	1.09	0.57 - 1.84	0.93	0.61 - 1.44
Stratified by Work Status						
Self employed	0.79	0.42 - 1.50	0.83	0.37 - 1.84	0.85	0.39 - 1.87
Not self employed	1.74	0.92 - 3.26	1.22	0.71 - 2.10	0.97	0.59 - 1.58
Full time	0.68	0.38 - 1.22	1.03	0.57 - 1.84	0.87	0.50 - 1.53
Part time	1.60	0.49 - 5.27	0.61	0.21 - 1.74	0.60	0.22 -1.68
Partly retired	**2.71**	**1.22 - 6.02**	1.78	0.81 - 3.94	1.40	0.68 -2.91

*Models adjusted for respondent age, gender, race, ethnicity, occupation, previous injuries, physical job, wages, tenure, weekly hours, and marital status

Discussion

As adults in the US continue to work longer, in one form or another, it is important to understand both the nature of this work arrangement as well as the implications for health. In these two longitudinal cohorts, we observed differing effects of job lock based on age, work status, and self-employment. We found that part-time and "partly retired" workers in both the 55-64 and 65 and older age groups to have higher rates of work-related injuries compared to full-time workers, after accounting for annual hours of work reported. However, only full or part-time workers aged 55-64, as well as those who were not self-employed, were at higher risk of work-related injuries if they reported job lock. When the analysis was repeated for a group of workers aged 65 and older, these effects were mostly absent. These results suggest that job lock, the feeling of being "stuck" at work out of a need for benefits, seemingly interacts differently with the work arrangement, and potentially the hazards of work, at these different stages in the life course.

We notably found job lock to impact the risk of work-related injuries among workers aged 55-64, when analyzed with repeated measurements of the exposure and outcome. Although the confidence intervals of our estimates lacked some precision, the incidence rate of work-related injuries was at least 21% higher for workers reporting job lock, compared to those not reporting job lock. These findings are generally consistent with the observation that job lock can longitudinally impact other measures of health in older workers before the age of 65, including insomnia, life satisfaction, and general wellbeing[3,71,72]. Also, while previous studies have found job lock to be more common after a work-related injury – our study contributes this longitudinal finding of the impact of job lock on subsequent work-related injuries, even after controlling for prior injury [69,70].

The effect modification of work arrangements could broadly suggest that for workers aged 55-64, being full or part-time could mean that employer benefits take on a greater significance that was not captured by the job lock question, which led to a stronger association between job lock and occupational injuries. Although self-employed workers may still feel financially tied to work, they could have more control over aspects of their health insurance or pay[4]. Partial or partly-retired work status is often found among workers who are still working in their career job, although at a reduced level[8]. This could mean that for self-employed or partly-retired workers, being in "job lock" is not necessarily a sign of some greater job strain. Those at higher incomes likely have a different experience of needing money than those who must work to cover their basic needs, so while both groups may report job lock, the question on its own does not distinguish this level of need.

It is also possible that self-employment or partial retirement could offer a form of job control that is important to workplace safety. It is proposed that older workers benefit from "job crafting" – the ability to make changes to their job tasks as well as social and cognitive aspects of work – which could be particularly important for older workers to keep up with the demands of work[62]. Self-employed or partial retired workers could find themselves in job lock, yet they may have more personal agency to mitigate the demands of work[8,125]. In the Karasek job strain model, workers face the greatest risk to their physical health when they have high psychological demands and low control or decision latitude at work[137].

Someone with greater control over their schedule, as with self-employment, may be able to moderate their health and workload better to avoid injury. Schedule control becomes important as overtime as well as longer daily or weekly hours increase the risk of injury at work[74]. Older workers with greater control over their schedules may also be

able to craft a schedule with reduced hazards given their line of work. Among EMS workers, working part-time or night shifts were found to be protective against occupational injury and illnesses, and this was thought to be from reduced exposure to hazards unique to EMS work[66].

We also found that job lock differentially impacts older workers from age 55-64, compared to age 65 and older. After age 65, we found minimal evidence of an impact of job lock on the risk of occupational injury, as this effect was only present in the "partly-retired" group. It is clear that after age 65, workers underwent some major changes to their health insurance and finances. Most workers became eligible for and reported Medicare coverage after age 65. A larger proportion in this age group may have also received financial benefits from Social Security or pensions. These major changes to receive public income and insurance may have mitigated the effect of job lock. The job lock question, as asked, does not provide much room for nuance or a scaled response. That is, workers may still feel they "need" their job for income, but perhaps to a lesser extent at older ages, which the question does not address.

After age 65, the interaction of job lock with "partly retired" workers could also suggest a need to consider how perceptions of job lock change and interact with health past the age of 65[3]. Respondents may have different interpretations of the partly retired category depending on their age, or perhaps job lock is a greater sign of precarity for those who are at the edge of retirement. Taken together, these findings could suggest a need to revisit the job lock concept, which was validated among workers prior to age 65, to consider how these perceptions change and interact with health as workers delay retirement past traditional retirement age[3].

Our study has several strengths, namely that we used a longitudinal, repeated measures study design, which allowed us to assess job lock, our occupational

confounders, and work-related injuries at multiple time points, possibly increasing precision of estimates in our study[138]. By ensuring that the job lock outcome preceded the work-related injury in the study timeline, as well as our use of directed acyclic graphics to model the causal association, we were potentially able to identify causal associations between job lock and occupational injuries. We were limited by several aspects of the HRS survey, the first being that all of our study measures were self-reported, which could bias the study toward finding an association between job lock and injuries. We also had no measure of the severity of injury, only the relative frequency using a count variable. HRS has a response rate that is typically 80-90%, although it is possible that those who died or otherwise did not respond to the survey had different experiences than those who remained in the study, potentially biasing our results[131].

Conclusion

While most workers prefer to retire when their financial situation allows, not all workers will reach the financial state that allows them to do so[3,8,139]. This could place greater strain on workers to remain healthy and working in order to receive benefits from an employer, including income or health insurance. We found job lock to be a common phenomenon among older workers of both age 55-64 as well as age 65 and older in the Health and Retirement Study. While the rate of occupational injuries was similarly high for part-time and partly-retired workers in both age cohorts, we found that job lock was only associated with an increased risk of work-related injuries before age 65. By assessing effect modification across work arrangements, we also found that for workers age 55-64, job lock only had an effect among full and part-time workers. Workers who reported a "partly-retired" status, as well as self-employed workers, may have aspects of job control to mitigate the effects of job lock, or the job lock construct may simply be viewed differently by these groups. While job lock may present itself as an unique job

stressor or economic determinant of health, particularly with regard to occupational injuries, our findings suggest a greater need to explore this phenomenon as anchored to other relatable, real-world constructs that relate to the work arrangement, including full or part-time work. Future research could examine these work arrangements in greater detail with regard to employer-provided benefits, work hours, or the flexibility provided by employers for vacation, sick days, or scheduling.

Chapter 6: Discussion

Overview

In three manuscripts, this dissertation examines the disease burden, costs, and economic risk factors for work-related injuries among older adults in the US. This research occurs at a time when workers in the US increasingly delay retirement, working past the age of 65 even as social programs begin to kick in that should decrease the reliance on work, like Medicare and Social Security. While many do seem to retire as these public benefits become available, 1 in 5, or over 15 million US adults, could still be working past the age of 65 by 2030[140,141]. With rapid growth among workers past the age of 65, it becomes more critical to adapt methods and data sources to identify the burden of work-related injuries in this population. Furthermore, healthcare costs are a relatively unexplored aspect of the disease burden to older adults, even as it is known that workers' compensation is far less likely to cover work-related injuries with age, [11,13]. Lastly, even as greater financial needs prevent workers from retiring altogether, creating job lock, the paths workers take to balance their health and financial needs are under- studied in terms of workplace safety.

Work-related injuries among age 65+ Medicare enrollees

In Manuscript 1, we began with characterizing work-related injuries among Medicare fee-for-service enrollees aged 65 and older, using Medicare inpatient and outpatient claims. While BLS estimates that workers aged 65 and older have the highest rate of fatal occupational injuries of any age group, estimates of non-fatal injuries, such as the BLS SOII, are likely to undercount injuries, particularly for older workers in non-standard work arrangements[78,80].

From 2016-2019, we estimated an average annual incidence of 27.6 work-related injuries per 100,000 Medicare fee-for-service enrollees aged 65 and older. This could translate to 150 work-related injuries per 100,000 aged, working Medicare enrollees, based on employment rates in this age group[95]. From BLS, there were 458 non-fatal occupational injuries and illnesses that occurred per 100,000 workers aged 65 and older in 2019[95,99]. This may be expected since our denominator focused on mostly acute injury cases from specific healthcare settings, whereas BLS surveys employers and does not restrict injuries by the healthcare setting. It is noteworthy, however, that we also identified at least 400% as many agricultural injury cases as the BLS SOII. BLS, which reported 1960 cases of occupational injuries and illnesses to agricultural workers from 2016-2019, likely undercounts cases from self-employed workers and workers on small family farms, which could help to explain our substantially higher estimate of agriculture 7898 cases with agricultural injury mechanisms over the same time period[80].

Surveillance of work-related injuries is challenging, with perhaps the most centralized source of information coming from the BLS SOII for non-fatal injuries and illnesses, and the BLS Census of Fatal Occupational Injuries[78,99]. Other secondary administrative sources have been used for surveillance, including workers' compensation claims or hospital discharge and emergency department records collected at the state level[12,41,45,50]. By comparing outpatient and inpatient work-related injury claims, our study attempted an approach that translates to injury surveillance methods using inpatient and outpatient hospital records[41,45,50]. By providing these first incidence estimates of work-related injuries in Medicare population, our study helps to fill a gap in potential data sources that can be used to study work-related injuries among older adults.

We also found that 18% of these cases in our study had work-related indicators specific to Medicare billing, which did not require traditional WC or ICD-10-CM codes to be counted. These codes permit a slightly more neutral take than previous methods – a claim only needs a provider to indicate an "employment-related" condition or event, rather than a confirmed workers' compensation payer. Also, injuries can be counted for less specific mechanisms – a fall can be counted without an industrial area or scaffolding involved, or a transportation incident can be found without a heavy duty vehicle. We likely missed many work-related injuries due to a lack of workers' compensation coverage, incomplete coding of mechanisms, or a provider unaware that an injury was work-related, but our approach seems to have closed these gaps beyond what previous methods would allow.

Costs of work-related injuries to older adults

Manuscript 2 adapted the methods of our first study to examine the healthcare costs to Medicare enrollees following a work-related injury. Fewer than half of the medical costs for work-related injuries and illnesses in the US may be covered by workers' compensation[10]. For adults aged 65 and older, estimates vary widely but suggest that workers' compensation could pay for just 7-24% of agricultural injuries, or fewer than half of industrial injuries[11–13]. As a result older workers could take on a greater share of work-related injury costs than the general population.

In this case-only study, we hypothesized that Medicare enrollees would have fewer out-of-pocket costs following an injury if their initial injury claim was paid by workers' compensation. We found that workers' compensation paid for only 16.0% of the initial work-related injury claims found in Medicare. In support of our hypothesis, we found that in the 90 days following a work-related injury, the WC group overall had mean out-of-pocket Medicare costs (inpatient, outpatient, and skilled nursing claims) that were

$151 lower (95% CI 125, 177) than the non-WC group. We also noted that for the WC group, 90-day out-of-pocket costs were $601 (95% CI 398, 805) lower at the 90th percentile of costs than the non-WC group. At this upper percentile, the non-WC group was liable for $2465 (95% CI 2388, 2543) in total out-of-pocket costs.

While we found that workers' compensation may help to buffer Medicare enrollee costs, our study also fills a gap in research by quantifying healthcare costs to older adults for their work-related injuries. We compared our results to similar studies of working age adults, one of which found that in the 2-3 months after a workers' compensation paid claim, inpatient and outpatient costs to group health insurance were 32-41% higher than before the injury. Although we found a similar pattern in Medicare, we find that workers' compensation may be even less adequate for older adults than in the general working population. In our study, the WC group saw combined outpatient, inpatient, and skilled nursing facility costs increased by over 100% in the three months after the injury.

We also identified through time series models how enrollees have a greater number of Medicare claims following a work-related injury, although this occurs to a lesser extent when WC coverage is present. In the first week after the work-related injury, weekly rates of incurring inpatient and outpatient claims spiked relative to before the injury. However, at just four weeks after the injury the WC group returned to their baseline rate of incurring both inpatient and outpatient claims. For the non-WC group, the inpatient claim rate was elevated up to six weeks after the injury, while the outpatient claim rate was elevated until the end of the study period at week 12. We speculate that when workers' compensation is paying for at least some of enrollees' care, fewer Medicare claims may be submitted over time.

Job Lock and its effects on work-related injury

Manuscript 3 differs from our previous two studies in that we identified a base population of employed older adults, which allowed us to compare risks of work-related injuries by occupational exposures. We explored the effects of job lock, conceptualized as workers' perceptions that they are tied to their work for health insurance or income benefits[3]. Using publicly available data from the Health and Retirement Study, we ran our analysis in two separate cohorts based on age (55-64 and 65+), from 2010-2018.

In our longitudinal analysis, we notably found job lock to have an effect on the incidence rate of occupational injuries in the age 55-64 cohort (IRR 1.52, 95% CI 1.21-1.92), but not in the age 65 and older cohort overall (IRR 0.93, 95% CI 0.61-1.44). With partial support for our hypothesis, we offer some explanations as to why these results may differ by age group. It was clear in our study that after age 65, most respondents reported Medicare coverage, and many likely received Social Security benefits or income from pensions. Although workers often reported job lock past the age of 65, these greater financial supports may have mitigated some of the negative health effects of job lock. It is noteworthy that validation studies only consider job lock prior to the age of 65, as do most studies exploring the health effects of job lock[71,72,142]. Given the greater support from social programs like Medicare, as well as potentially differences among those who continue to work past the age of 65, our findings raise a point for future research to explore how job lock may operate differently with age.

In the age 55-64 cohort, we also found the effects of job lock were modified by the work arrangement. Essentially, workers who were partly retired or self-employed did not experience a greater risk of work-related injuries from job lock. Meanwhile, these effects were present among full-time (IRR 1.56, 95% CI 1.19-2.04), part-time (IRR 1.97, 95% CI 1.13-3.43), and workers who were not self-employed (IRR 1.58, 95% CI 1.24-

2.06). These results could suggest that workers who consider themselves self-employed or partly-retired have greater control over their work environments compared to those in full or part-time arrangements. This is also consistent with how these work arrangements have been viewed in the literature, suggesting that workers who have greater control over different aspects of their work have lower risks of injury[8,125]. It is also possible that full or part-time workers rely on their work to support them differently, perhaps for basic needs. Self-employed or partially retired workers, on the other hand, may rely on work in a different sense, perhaps viewing their work as more supplemental to support their preferred lifestyle.

Our study adds to a relatively small body of literature exploring the health effects of job lock[3,69–72]. Perhaps uniquely, we explore these effects with a longitudinal repeated measures design, improving the precision of our estimates. Past studies of job lock have identified associations between job lock and general wellbeing, life satisfaction, or in a more recent cross sectional study, insomnia[3,71,72]. Job lock has been found to be quite common among workers with a recent work-related injury, although our study appears to be the first to estimate causal effects of job lock on work-related injuries through our longitudinal design[69,70].

Strengths & Limitations

This dissertation used multiple data sources to explore different yet complementary aspects of work-related injuries among older adults in the US. The methods used in Aim 1 and Aim 2 included a comprehensive approach to identify work-related injuries from healthcare administrative data, based on methods from the literature and by leveraging unique variables collected in Medicare claims. The Medicare claims data lacked employment information, so we were unable to calculate incidence rates in terms of a denominator of employed Medicare enrollees. This limited the

generalizability of our findings, as well as our ability to validate whether our claims definition for a work-related injury actually coincided with someone's employment status.

We were however able to use Medicare claims to follow work-related injury cases longitudinally in claims data and assess changes in costs over time. This allowed us to approach our research question broadly at first, using a difference in differences design to establish excess out-of-pocket costs following a work-related injury, particularly in the absence of WC coverage. Once the effect was established, we explored these costs in depth using quantile regression to estimate greater differences among those incurring the highest costs for their healthcare. One limitation of this approach was that it was not comprehensive of Medicare enrollee costs – we estimated costs from inpatient and outpatient facility claims, as well as skilled nursing facilities, but these claims did not cover other types of healthcare services such as prescription drug fills, durable medical equipment, or physician billing for office visits. Although these costs seemed substantial over such a short time, these effects could differ for other types of services billed to Medicare. Other Medicare claim types may differ in costs or how likely workers' compensation is to cover the service. In addition, we cannot assume the effects occur past the 90-day window of our study, warranting further study of long-term healthcare costs.

Aim 3 was somewhat complementary to Aims 1 and 2 in that we could actually estimate work-related injury rates with a denominator of older workers. Using the HRS survey, we were able to relate workers' reported hours to their injuries, calculating incidence rates of injury in terms of both total workers and a full-time equivalent (FTE) denominator. We gained precision from a longitudinal, repeated measures design to estimate the effects of job lock. However, unlike Medicare claims, all of the study measures were self-reported, and our study may be impacted by a response bias. Also,

while Medicare claims provided detailed diagnosis codes, the effects of job lock on injury risk in HRS cannot be contextualized by how severe the injuries may have been. While we found in some cases that those in job lock had higher rates of injury, we do not know if their injuries were more severe or simply more common.

Public health implications

Existing occupational injury surveillance likely underestimates the burden of work-related injuries for workers past the age of 65. As this workforce demographic continues to grow, it becomes more important to accurately monitor and study work-related injuries to direct prevention efforts and keep up with the disease burden in this population. This study serves to confirm that work-related injuries can be detected in Medicare claims using practical methods from the literature and from codes used by Medicare to identify and pay for (or avoid paying) a work-related injury claim.

The work-related injury burden is also more dynamic than just case counting. This study provides some new paths to keep up with this burden in the elderly, including the longitudinal study of health and economic outcomes. After hospital discharge, an individual's experience with an injury is far from over, and Medicare claims can be used to track hospital readmissions, follow up care, and healthcare costs that may have significant impacts on individuals or the healthcare system.

Workers' compensation, as we found, is often inadequate for older adults even in the short term. While it is known that many of the costs of work-related injuries have shifted from workers' compensation to Medicare, our study estimates impacts on individuals rather than just the Medicare program. As more adults work past the age of 65, these excess costs to Medicare enrollees may be a worsening problem, requiring greater attention from both workers' compensation and Medicare payment policy. Higher costs for work-related injuries may add to workers' struggle to retire with adequate

financial resources. Severe injuries could force workers to retire before they are financially ready, intensifying disparities from age, gender, race, ethnicity, comorbidities, or healthcare coverage.

Occupational injury, as we have seen in this study, can be a major disruptive force to the health and wellbeing of older adults. Around age 65, most workers appear to be just a few short years from retirement, yet an occupational injury could have major health and financial implications for many years longer. This struggle to retire, as evident from job lock, also appears to impact workplace safety differentially with age. It may not be coincidence that job lock had less effect on injuries after age 65, at a time when many became eligible for social programs like Medicare and Social Security. This may suggest a safety benefit to expanding these programs. It could also suggest that greater job control or a phased, "partial retirement" option, which many working past age 65 appear to have, may be an important focus of policy or intervention in the aging workforce.

Conclusion

This study was first to examine the incidence of work-related injuries and their subsequent out-of-pocket costs from Medicare claims. Workers' compensation likely protects Medicare enrollees from incurring some out-of-pocket costs, but this coverage is not common. When present, however, workers' compensation does not seem to cover all excess healthcare expenses from the work-related injury. These costs have implications for the nature of why most adults continue to work past the age of 65, which appears to be for financial reasons. Job lock, a measure of this financial barrier to retirement, appears to have implications for workplace safety prior to age 65, particularly for full and part-time workers. Past the age of 65, job lock, as defined in the current literature, does not appear to confer a hazard upon workers. Nonetheless, we find that work-related injuries after the age of 65 are a serious burden to workers' health and their

healthcare costs, and they occur at a rate that is often close to their age 55-64 counterparts. Taken together, the findings of this study form a basis to improve occupational injury surveillance, motivate future research to protect workers from high healthcare costs for their work-related injuries, and further explore occupational hazards among those who continue working past the age of 65.

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Appendix

Table A1. Summary of literature to identify work-related injuries from administrative databases.

Author(s)	Year	Title	Purpose of Study	Population / Data	Methods	Findings / Sensitivity of Methods	Conclusions	Limitations
Bush, Ashley M; Bunn, Terry L; Liford, Madison	2021	Identification of work-related injury emergency department visits using International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes	To compare work-related ED visits identified by expected payer and ICD-10-CM codes, and to assess changes in the capture of work-related injuries by both methods.	Emergency department visits from Kentucky outpatient services database 2016-2019	Divided expected payer into WC and non-WC. Two researchers manually assessed all ICD-10-CM external cause codes for likelihood of being work-related, and a third team member weighed in if there was disagreement.	A total of 63459 cases identified by work-related external cause and 87361 cases identified by WC. Among work-related external causes, 50.5% also had WC as expected payer. Among WC cases, only had a work-related external cause code. External cause codes identified 36% more work-related visits than WC alone. Falls were the most frequent mechanism of injury. If WC was the expected payer, machinery was the most	ICD-10-CM external cause codes can enhance the capture of work-related injuries compared to using only the WC expected payer.	External cause codes are not required in state ED visit data, incomplete external cause codes may undercount cases. Study lacks a gold standard for comparison. Identifies number of visits, not individual injuries, which may overcount cases.

						common mechanism.		
Kurth, Laura; Casey, Megan; Chin, Brian; Mazurek, Jacek M.; Schleiff, Patricia; Halldin, Cara; Blackley, David J.	2021	Medical claims paid by workers' compensation insurance among US Medicare beneficiaries, 1999–2016	To identify Medicare claims with WC as primary payer and assess characteristics, healthcare utilization, and healthcare costs.	1999-2016 Medicare FFS beneficiaries and claims	Cross-sectional analysis of 1999-2016 FFS Medicare claims for injuries and illnesses with WC as primary payer. Characterized injuries and illnesses by principle or admitting diagnosis code. Summarized utilization by claim type. Summarized costs by amount paid to WC and Medicare.	Large spike in WC paid claims from 2006-2010, which drops off in 2016. This aligns with a decline in WC-covered workers and Medicare and Medicaid SCHIP Extension Act of 2007 enforcing MSP payer rules within 18 months of passage. The majority of WC claims were found in the Carrier file (physician claims).	Among Medicare claims with WC as primary payer, WC paid 74% of costs to providers. Study helps to identify healthcare burden of occupational injury and illness to Medicare beneficiaries and identifies a need for more comprehensive surveillance.	Study likely undercounts work-related injuries and illnesses by only using WC to identify work-related claims.
Scott, Erika; Hirabayashi, Liane; Graham, Judy; Krupa,	2021	Using hospitalization data for injury surveillance in agriculture, forestry and	To develop and test an agriculture, forestry, and fishing crosswalk	MA, VT, and NY state hospital discharge	Two occupational health and safety specialists review over	Crosswalk developed to include "true" agricultural codes as well as suspected	An easily reproducible crosswalk, best suited for identifying true	External cause codes are not required in state hospital

Nicole; Jenkins, Paul		fishing: a crosswalk between ICD10CM external cause of injury coding and The Occupational Injury and Illness Classification System	between ICD-10-CM external cause codes and OICCS.	data 2016-2017	6000 ICD-10-CM external cause codes for agricultural, forestry, or fishing related codes. Reviewers discussed discrepancies and brought unresolved codes to the entire research team for discussion. A lead reviewer finalized the list and assigned codes to each industry (agriculture, fishing, forestry) and assigned confidence (true, suspected) to the code. Applied crosswalk to hospital data	agriculture, forestry, and fishing codes, totaling 263 codes. Of 9969 cases identified from applying the crosswalk, 963 had a "true" agricultural code, the rest were suspected cases.	agricultural cases.	discharge data, incomplete external cause codes may undercount cases. Study lacks a gold standard for comparison. Agricultural codes may not necessarily capture cases related to work.

					to summarize cases identified.			
Kica, Joanna; Rosenman, Kenneth D.	2020	Multisource surveillance for non-fatal work-related agricultural injuries	To describe a multisource surveillance system for non-fatal work-related agricultural injuries and compare estimates with BLS SOII data.	2015-2016 Michigan Hospital and ED data linked to WC	Hospital/ED records were manually reviewed for indication that injury was from work on a farm, and farm-related ICD-9 / ICD-10 codes were also used to identify cases. Work-related injury rates were calculated using the 2012 Census of Agriculture to calculate the denominator.	Reviewed 4467 medical records with farm-related ICD codes and determined only 35% to be work-related. Of the work-related farm injuries, expected payers were commercial (42%), WC (24%), Medicare/Medicaid (24%), and self (10%). BLS rates of non-fatal farm-related injuries were higher in 2015, similar in 2016 to the study estimates.	System provides a reliable estimate of non-fatal work-related farm injuries, with more detail than BLS. A surveillance system based on WC alone would seriously undercount cases.	Data did not contain cost. No gold standard for comparison. System would miss work-related cases for Michigan residents treated out-of-state or who were working for an out-of-state employer.
Harduar Morano, Laurel; Richardson, David; Proescholdbell, Scott	2019	Descriptive evaluation of methods for identifying work-related emergency department injury visits	To evaluate three methods of identifying work-related injuries: WC, ICD-9 work status codes, and ICD-9	2010-2013 NC syndromic surveillance system	Identified ED visits with WC, ICD-9 work status codes, or ICD-9 external cause codes.	Identified 133156 work-related ED visits: 69% from WC, 18% work status e code, and 13% other work-related e codes. WC alone	Work status e codes (e.g. civilian activity done for income or pay) can help to supplement identification of work-relatedness	Study lacks a gold standard for comparison. E codes are not required on hospital discharge

			external cause codes		Compared visits that had one, two, or all three indicators. Manually reviewed a sample of admission notes (N=800) for work-related notes, as a sensitivity analysis.	identified 52%, while 17% had both WC and a work-related e code, leaving 31% identified only by a work-related e code. When WC was expected payer, 53.0% agreement with admission notes as work-related, and without WC, work-related e codes had 46.0% agreement with admission notes.	in addition to WC. Location e codes (e.g. farm, industrial) should be used with caution, but may be helpful in combination with other work-related codes.	data and the accuracy of e codes was not evaluated.
Missikpode, C; Peek-Asa, C; Wright, B; Ramirez, M	2019	Characteristics of agricultural and occupational injuries by workers' compensation and other payer sources	To determine the sensitivity and specificity of WC as an indicator of work-related agricultural injuries and describe characteristics of injuries by payer.	Iowa Trauma Registry 2005-2013, patients with a rural residence	Farm-related injuries were identified by a flag in the database, based on ICD-9 codes. Work-related definition required injury to occur at work or during an activity related to work. Sensitivity and	WC had 64% sensitivity and 96% specificity to identify rural, nonagricultural occupational injuries and 19% sensitivity / 99% specificity to identify agricultural work-related injuries. For age 65+, sensitivity was lower for both agricultural (7%) and nonagricultural	WC has low sensitivity to identifying work-related injuries but injuries found by WC are accurately identified as work-related. Study found some evidence of shifting of work-related injury costs to Medicare for older workers.	Less generalizable since injuries from hospital data are more severe, did not capture full burden of work-related injuries. Missing primary payer for 23% of records.

					specificity were calculated of the WC expected payer to identify work-related status. Trauma registry work-related indicator was considered the gold standard. Logistic regression was used to model odds of a work-related injury billed to WC, adjusting for age, sex, severity, mechanism, and trauma care level.	(55%). Compared to age 18-64, age 65+ had lower odds of WC as payer for agricultural work-related injuries (OR=0.24) and rural nonagricultural work-related injuries (OR=0.68).		Limited by accuracy of reporting of events as work-related, and reporting of the WC payer.
Kica, Joanna; Rosenman, Kenneth D.	2018	Multi-source surveillance for work-related crushing injuries	To describe a multisource surveillance system for work-related crushing injuries and compare	2013-2015 Michigan Hospital ED data link to WC claims and death certificates	Hospital and ED records were linked to WC reports, and a state surveillance system for	WC was the expected payer in 64% of work-related injuries from hospitals/ED. Among 3137 work-related	Identified 2.5 times as many work-related crushing injuries as BLS.	System would miss work-related cases for Michigan residents treated out-of-state or

			estimates with BLS SOII data.		acute traumatic fatalities . Hospital/ED records were manually reviewed for work-relatedness. Work-related injury rates were calculated using the Current Population Survey to calculate the denominator.	crushing injuries from hospitals/ED, only 7% matched to WC.		who were working for an out-of-state employer. Did not have a gold standard.
Sears, Jeanne M.; Bowman, Stephen M.; Blanar, Laura; Hogg-Johnson, Sheilah	2017	Industrial Injury Hospitalizations Billed to Payers Other Than Workers' Compensation: Characteristics and Trends by State	To describe demographic and injury characteristics of industrial injury hospitalizations, and assess whether industrial injuries are more likely to be billed to non-WC payers over time.	1998-2009 HCUP State Inpatient Databases for CA, CO, and NY	Compared payers for industrial injuries by state and year, both as WC vs non-WC and across payers (Medicare, Medicaid, private insurance, other coverage, self-pay/no charge). Ran	ICD-9 E849.3 industrial place, primary payer WC	A decrease was seen in the % of industrial injuries billed to WC over time for CA (66% to 59% from 2003-2009) and CO (70% to 58% from 1998-2009), while NY hovered around 61-66% from 1998-2009. Age 65+ had the highest odds of being billed to a non-WC source in all states, and	Cost shifting was observed from WC to Medicare, particularly for older workers. In some states there is an increase in non-WC payers to cover healthcare for industrial injuries.

					a logistic regression model for each state to estimate the average annual change in the odds of an injury not being billed to WC, adjusting for gender, race/ethnicity , categorical age, and severe injury (AIS >=3).		Medicare was billed most often, 57% in CA, 43% in CO, and 49% in NY.	
Landsteiner, Adrienne M. K.; McGovern, Patricia M.; Alexander, Bruce H.; Lindgren, Paula G.; Williams, Allan N.	2015	Incidence Rates and Trend of Serious Farm-Related Injury in Minnesota, 2000–2011	To examine rates and trends of farm injuries in Minnesota from 2000-2011	Minnesota Hospital Discharge Data 2000-2011	Grouped ICD-9 external cause codes as "probable" or "possible" farm injuries. Estimated denominator as number of individuals living on a farm in Minnesota, using ACS and Minnesota state data.	Identified 29459 farm injuries, 20.5% "probable" and 79.5% "possible", for an annual rate of 14.0-18.5 injuries per 1000 individuals living/working on a farm. Estimated 7500 to 10400 annual farm injuries after accounting for missing e codes, or 48-74 injuries per 1000	Hospital discharge data provide a feasible and more complete data source for surveillance of agricultural injuries compared to other data sources	By only using inpatient data, study undercounts less serious injuries. Study lacks a gold standard for comparison. E codes are not required on hospital discharge data and the accuracy of e codes was

					Inflated estimated to account for missing e codes (10%), as found in HCUP data	individuals living/working on a farm. Only 2.2% of injuries covered by WC, 72.4% by private health insurance. A total of 28 deaths found from 2000-2011, over 90% of nonfatal cases were discharged to home. Over half (53%) of cases were admitted through the emergency department.		not evaluated.
Largo, Thomas W.; Rosenman, Kenneth D.	2015	Surveillance of work-related amputations in Michigan using multiple data sources: results for 2006-2012	To describe work-related amputations from a multi-source surveillance system and compare estimates to WC and BLS SOII.	2006-2012 Michigan hospital ED and discharge data linked to WC	Multi-source surveillance reviewed hospital and ED medical records to determine if amputations were work-related and then attempted to link cases to WC claims. Described cases found from medical records-only,	Identified 4104 work-related amputations, from medical record-only (44.5%), medical record and WC (43.4%), and WC only (12.9%). WC was expected payer for 66% of cases. In most years the multi-source estimate was over twice that of WC or BLS SOII alone. Across all age	The multi-source system more accurately identified the true number of work-related amputations than BLS or WC estimates alone.	System would miss work-related amputations for Michigan residents treated out-of-state or who were working for an out-of-state employer. A gold standard was not available, although

					WC-only, and medical records linked to WC. Compared multi-source estimates by year to WC and BLS SOII. Described work-related amputation rate by age group, sex, industry, and cause.	groups men had a higher amputation rate than women, overall 88% of amputations were for men. Sharp objects were the most frequent cause of injury.		medical records were close to a gold standard.
Gross, Nathan; Young, Tracy; Ramirez, Marizen; Leinenkugel, Kathy; Peek-Asa, Corinne	2015	Characteristics of Work- and Non-work-Related Farm Injuries	To characterize the burden of non-fatal farm injuries by work-relatedness	Iowa Trauma Registry 2005-2011	Farm-related injuries were identified by a flag in the database, based on ICD-9 codes. Work-related definition required patient to be working for compensation at time of injury, injury had to occur at work or while traveling for work, or an	Work-related farm injuries had little effect on injury severity. Work-related farm injuries had longer length of stay. Those above age 65 were more likely to be injured in non-work activities.	Approximately half of farm injuries were work-related. Distinguishing work vs non-work farm-related injuries is important to interventions.	Each hospital enters data into the registry, and quality and timing of data may vary and impact results.

					activity related to the job. These factors were used to determine work-related vs nonwork-related status of the farm injury. A logistic regression was run to examine associations between farm injury characteristics and injury severity, discharge status, and length of stay.			
Kica, Joanna; Rosenman, Kenneth D.	2014	Surveillance for work-related skull fractures in Michigan	To describe a multisource surveillance system for work-related skull fractures and compare estimates with BLS SOII data.	2010-2012 Michigan Hospital ED data link to WC claims and death certificates	Hospital and ED records were linked to WC reports, and a state surveillance system for acute traumatic fatalities . Hospital/ED	Of 318 work-related skull fractures, 88% were from hospital/ED reports and 52% were from WC cases. WC was the expected payer in 56% of cases. Highest incidence of skull	If only WC were used for surveillance, only 37% of work-related skull fractures would have been identified. BLS underestimated counts as well, only 54% of the total identified	Data did not contain cost. No gold standard for comparison. System would miss work-related cases for Michigan residents treated out-

					records were manually reviewed for work-relatedness. Work-related injury rates were calculated using the Current Population Survey to calculate the denominator.	fracture in older workers age 65+.	from multi-source surveillance.	of-state or who were working for an out-of-state employer.
Sears, Jeanne M.; Bowman, Stephen M.; Silverstein, Barbara A.; Adams, Darrin	2012	Identification of work-related injuries in a State Trauma Registry	To assess three methods of identifying work-relayed injuries, using WC payer, ICD-9-CM, and a work-related indicator from the state trauma registry.	1998-2008 Washington Trauma Registry data linked to WC claims	Compared the WTR trauma database indicator ("Work Related? Yes/No") to WC and ICD-9-CM work-related definition from Alamgir et al. Calculated sensitivity of all three methods alone and in combination, for seven total	Sensitivity of indicators: WTR indicator (87%), WC (89%), ICD-9-CM e codes (60%), all three in combination (96%).	A simple work-related question in the database (e.g. work-related, "Yes/No") was highly sensitive to identifying work-related injuries and may help to identify injuries that are exempt/excluded or otherwise not reported to WC. External cause codes may improve estimates by have poor sensitivity on their own.	A gold standard was not available. With a large number of injuries in the database unrelated to work, the number of false positives was close to the number of true positives for some strata.

					estimates. True positives were the trauma database indicator linked to a WC claim.			
Kica, Joanna; Rosenman, Kenneth D.	2012	Multisource surveillance system for work-related burns	To describe a multisource surveillance system for work-related burns and compare estimates with BLS SOII data.	2009 Michigan Hospital ED data link to WC claims and death certificates	Hospital and ED records were linked to WC reports, and a state surveillance system for acute traumatic fatalities . Hospital/ED records were manually reviewed for work-relatedness. Work-related injury rates were calculated using the Current Population Survey to calculate the denominator.	Among 1461 work-related burns, most were from hospital records (85%) and then WC (21%), and 12% of records were from both hospital and WC. Identified nearly three times as many work-related burns as BLS.	Multi-source surveillance more accurately identified the burden of work-related burns than WC alone or BLS data.	System would miss work-related cases for Michigan residents treated out-of-state or who were working for an out-of-state employer. Did not have a gold standard or compare estimates across years. Data lacks information on the costs of burns.

Alamgir, H.; Koehoorn, M.; Ostry, A.; Tompa, E.; Demers, P.	2006	An evaluation of hospital discharge records as a tool for serious work related injury surveillance	To compare methods of identifying work-related injuries among sawmill workers using hospital discharge records.	1989-1998 hospital discharge records from British Columbia	Identified work-related injuries with WC expected payer and ICD-9-CM work-related external cause codes. Work-related ICD-9-CM codes were determined by a digit indicating farm, mine and quarry, industrial place and premises, or a 4th digit for occupation (e.g. railway employee, crew)	Among 1885 hospital admissions from the sawmill cohort, 24% were work-related by WC payer, 25% were work-related by e code. Combining methods, 29% of admissions were work-related (Kappa = 0.75, p<0.01). When the analysis was limited to active sawmill workers, 370 admissions were 41% work-related by WC payer, 43% work-related by e code, and 47% total work-related (Kappa=0.77, p<0.01).	E codes and WC payer are able to effectively identifying serious work-related injuries that require hospital admission. There was good agreement between the indicators.	Study used expected payer but did not verify in actual WC claims data. Limited by the accuracy of external cause codes.

Table A2. Summary of literature of factors influencing the payment and healthcare costs of work-related injuries.

Author(s)	Year	Title	Purpose of Study	Population / Data	Methods	Findings / Sensitivity of Methods	Conclusions	Limitations
Nicholson VJ, Bunn TL, Costich JF	2008	Disparities in work-related injuries associated with worker compensation coverage status	To describe work-related injuries by WC insurance coverage status.	2005 ED visits to an academic health center	Identified work-related injuries as reported by ED staff, WC coverage status was self-reported from workers. Compared insured vs uninsured workers by injury characteristics and demographics	Of 1023 patients with work-related injuries, 20% did not have WC coverage. 32% of Latino workers did not have WC, compared to 19% of non-Latino workers. For workers without WC, 92% lacked any kind of health insurance. WC uninsured group had lower ED visit charges than the insured group. Uninsured also seemed to have more mild injuries.	Uninsured patients may have had lower charges because they decline procedures. Uninsured with more mild injuries in ED may be reflection of lack of access to appropriate services. More moderate and severe injuries among Latino workers, consistent with literature.	Self-reported WC coverage, study did not confirm status. Even covered workers may underreport their WC coverage. Potential bias if workers did not know their right to WC coverage.

Bhattacharya A, Park RM	2012	Excess healthcare costs associated with prior workers' compensation activity	To examine if prior WC activity predicts frequency and costs of healthcare claims from other medical insurance.	2001-2005 MarketScan claims	Analyzed monthly group medical expenses with and without prior WC. Modeled odds of filing group medical claim, by demographic, prior WC, industry, insurance type, union, salary worker, hourly worker. Ran linear regression by industry for average monthly expenditures when medical claims were filed.	Those with prior WC were more likely to file a group medical claim (OR=1.25) and had higher average monthly medical costs (203.72 vs 160.29) than those with no prior WC claim.	Those with prior WC claims are medically more expensive to group health plans than those without prior WC claims. In part, employer liability costs for work-related injuries and illnesses is shifted to group medical plans. Increase in medical expenses with age, and higher utilization among female workers.	Unable to classify Marketscan claims as work-related. May not be a nationally representative sample since population is employed by large corporations. Occupational and personal risk factors were mostly unknown, study used proxies.

Leigh JP, Marcin JP	2012	Workers' compensation benefits and shifting costs for occupational injury and illness	Estimate incident costs of occupational injuries and illnesses by year, and estimate which groups pay for costs not covered by WC.	BLS SOII and BLS CFOI, NCCI average benefit payments, all from 2007	Calculated average and total medical and indemnity benefits by type of injury (nonfatal, fatal, total/partial disability, permanent and tempory disability, days away from work). Calculated medical, indirect, and total costs by payer.	Less than half of medical costs in 2007 were paid by WC, and 25% were paid by public programs. Approximately 9% were paid by patient out of pocket.	Provides incidence-based estimates of WC benefits and measures the extent of WC cost shifting.	Assumptions were made to create medical-only vs indemnity estimates, using time away from work. Limitations of sampling from BLS data, 40% of cases never reported to BLS. Some occupations are also not sampled in the BLS.
Sears JM, Blanar L, Bowman SM, et al	2013	Predicting work-related disability and medical cost outcomes: estimating injury severity scores from workers' compensation data	Describe the degree to which AIS severity score predicts work-related disability and medical costs	Washington state nonfatal WC claims, linked to state trauma registry, 1998-2008	Predictors: early hospitalization (inpatient within 30 days of injury), ISS, and combined early hospitalization and ISS. Competing risks survival analysis to predict 1) end of lost-time compensation without total	ISS significantly associated with work-related disability and medical costs. Rural injuries had higher severity, costs, and lost work days. Early hospitalization was also as good a predictor as injury severity, and using both created more informative models.	Injury severity is a potential confounder in occupational health studies.	

					permanent disability (TPD), and 2) TPD.			
Groenewold MR, Baron SL	2013	The proportion of work-related emergency department visits not expected to be paid by workers' compensation: implications for occupational health surveillance, research, policy, and health equity	To examine trends and identify correlates of work-related ED visits not expected to be paid by WC.	2003-2006 National Hospital Ambulatory Medical Surveys	Work-related ED visits determined from narrative text, turned into a yes/no question. WC as expected payer was also determined by record abstraction. Covariates were age, sex, gender, race/ethnicity, hospital geographic location, clinical characteristics. Ran logistic regression	Medicare was expected payer for 1.7% of visits, WC for 60.4%, self pay 11.4%, Medicaid 3.5%, private insurance 21.4%. Of non-WC ED visits, more likely to be paid by Medicare/Medicaid if Black (19% Black patients vs 11% non-black patients). Black/other race/ethnicity had higher odds of non-WC than white. For-profit hospitals and hospitals in the South (ref= West) had higher odds	From 2003-2006, increasing proportion of work-related ED visits for not expected to be paid by WC. Work-related illnesses were less likely to be paid by WC than work-related injuries. Burden of payment for work-related injuries, when WC does not pay, is more likely to go to minorities	No quality indicator of the information for work-relatedness or expected payer. Only covers ED visits, a number of work-related injuries happen outside the ED. May have underestimated WC based on the abstraction method.

					model for WC payer.	of non-WC than not-for-profit hospitals. No differenc in rural/non-rural hospital location for WC as expected payer.	and public or private insurance.	
Green DR, Gerberich SG, Kim H, et al	2019	Knowledge of work-related injury reporting and perceived barriers among janitors	To identify perceived barriers to reporting work-related injuries.	Full-time unionized janitors in Minnesota, responding to questionnaire at baseline and 6-month follow up, 2016-2017	Baseline and follow up questionnaire asking if injury/illness reported to employer, and reasons if not reported. Asked if aware of OSHA log and WC. Asked if ever filed a WC claim. Also compared responses between group that	56% of respondents did not know what WC is. 16% had filed for WC before. One quarter of janitors perceived barriers to WC reporting. Most common barriers were fear of getting into trouble, confusion or reporting, and belief that injuries were part of the job.	Lack of knowledge of injury reporting is a problem among janitors. Providing information helped to reduce perceived barriers in reporting injuries.	Low response rates. May not generalize to non-union janitors, who may have more barriers.

					did/did not receive an educational intervention.			
Sears JM, Edmonds AT, Coe NB	2020	Coverage Gaps and Cost-Shifting for Work-Related Injury and Illness: Who Bears the Financial Burden?	To present mechanisms of cost burden of occupational injuries and illnesses to workers and public programs	Literature review	Review of literature and construction of flow diagram	Pathway to burden to workers: 1) accepted WC claims may be inadequate to cover healthcare costs 2) employer/individual health insurance does not cover income replacement 3) uninsured workers 4) coinsurance, deductibles, premiums for insurance if WC does not pay Vulnerable workers have	More detailed/comprehensive approaches are needed to understand cost shifting and financial burden.	Literature review

						greater disparities to accessing WC. Gender, wealth, education, race/ethnicity, immigration status may all be barriers to WC process. Greater number of non-standard and precarious jobs that may not be covered by WC.		

Huang Z, Friedman LS	2020	Occupational injury surveillance pyramid description and association of medical care utilization with low income among work-related injuries	To describe the level of care for occupational injuries in the US and evaluate whether care utilization differs for low income patients.	2004-2016 NHIS	Work-related injuries identified by survey question. Low income determined by family poverty ratio. Level of care used hierarchy: hospitalization , ER visit, doctor's office/clinic visit, use of emergency vehicle, telemedicine only. Logistic regression models, exposures were injured at work, low income, and the interaction. Outcome was level of care.	53% of work-related injuries were treated outside of a hospital. Work-related injuries were less likely to be admitted than non-work-related injuries. Among work-related injuries, low-income patients were more likely to be admitted to the hospital.	Injury prevention tends to ignore injuries treated outside the hospital, but a significant number of injuries are treated outside of the hospital that result in missed days away from work.	Self-reported measures, missed days reported in intervals of time and not continuous. Fatal cases would be missed by survey.

Baidwan NK, Ramirez MR, Gerr F, et al	2021	Cost, Severity and Prevalence of Agricultural-Related Injury Workers' Compensation Claims in Farming Operations from 14 U.S. States	To characterize the burden of agricultural injury and estimate costs, for both medical-only claims and claims leading to death and disability.	2010-2016 WC data from a large insurance company covering agricultural workers in 14 states	Ran GLMs to estimate prevalence ratio of disability/death vs medical-only claims, and to estimate mean costs of injuries. Calculated attributable costs of disability/death and medical-only claims.	Of 1066 WC claims, 2/3 were medical-only and 1/3 were death/disability. 96% of costs were attributed to death/disability. Medical-only claims had mean cost of 1462, median 488, much higher costs for death/disability (mean 18-416k).	Agricultural injuries present a large financial burden and workers experience a large number of injuries. Slips/trips/falls, flying objects, collisions were the most costly and severe claims.	Generalizable to policy holders but perhaps not agricultural workers as a whole. Underreporting is common in WC. Unable to estimate indirect costs.
Sears, Jeanne M.; Bowman, Stephen M.; Blanar, Laura; Hogg-Johnson, Sheilah	2017	Industrial Injury Hospitalizations Billed to Payers Other Than Workers' Compensation: Characteristics and Trends by State	To describe demographic and injury characteristics of industrial injury hospitalizations, and assess whether industrial injuries are more likely to be billed to non-WC payers over time.	1998-2009 HCUP State Inpatient Databases for CA, CO, and NY	Compared payers for industrial injuries by state and year, both as WC vs non-WC and across payers (Medicare, Medicaid, private insurance, other coverage, self-pay/no charge). Ran a logistic regression	ICD-9 E849.3 industrial place, primary payer WC	A decrease was seen in the % of industrial injuries billed to WC over time for CA (66% to 59% from 2003-2009) and CO (70% to 58% from 1998-2009), while NY hovered around 61-66% from 1998-2009. Age 65+ had	Cost shifting was observed from WC to Medicare, particularly for older workers. In some states there is an increase in non-WC payers to cover healthcare for industrial injuries.

					model for each state to estimate the average annual change in the odds of an injury not being billed to WC, adjusting for gender, race/ethnicity, categorical age, and severe injury (AIS >=3).		the highest odds of being billed to a non-WC source in all states, and Medicare was billed most often, 57% in CA, 43% in CO, and 49% in NY.	
Missikpode, C; Peek-Asa, C; Wright, B; Ramirez, M	2019	Characteristics of agricultural and occupational injuries by workers' compensation and other payer sources	To determine the sensitivity and specificity of WC as an indicator of work-related agricultural injuries and describe characteristics of injuries by payer.	Iowa Trauma Registry 2005-2013, patients with a rural residence	Farm-related injuries were identified by a flag in the database, based on ICD-9 codes. Work-related definition required injury to occur at work or during an activity related to work. Sensitivity and specificity were calculated of the WC expected payer to	WC had 64% sensitivity and 96% specificity to identify rural, nonagricultural occupational injuries and 19% sensitivity / 99% specificity to identify agricultural work-related injuries. For age 65+, sensitivity was lower for both agricultural (7%) and nonagricultural (55%). Compared to age 18-64, age 65+ had lower odds of WC as	WC has low sensitivity to identifying work-related injuries but injuries found by WC are accurately identified as work-related. Study found some evidence of shifting of work-related injury costs to Medicare for older workers.	Less generalizable since injuries from hospital data are more severe, did not capture full burden of work-related injuries. Missing primary payer for 23% of records. Limited by accuracy of reporting of events as work-related, and reporting

					identify work-related status. Trauma registry work-related indicator was considered the gold standard. Logistic regression was used to model odds of a work-related injury billed to WC, adjusting for age, sex, severity, mechanism, and trauma care level.	payer for agricultural work-related injuries (OR=0.24) and rural nonagricultural work-related injuries (OR=0.68).		of the WC payer.
Kurth, Laura; Casey, Megan; Chin, Brian; Mazurek, Jacek M.; Schleiff, Patricia; Halldin, Cara; Blackley, David J.	2021	Medical claims paid by workers' compensation insurance among US Medicare beneficiaries, 1999–2016	To identify Medicare claims with WC as primary payer and assess characteristics, healthcare utilization, and healthcare costs.	1999-2016 Medicare FFS beneficiaries and claims	Cross-sectional analysis of 1999-2016 FFS Medicare claims for injuries and illnesses with WC as primary payer. Characterized injuries and illnesses by principle or admitting diagnosis code.	Large spike in WC paid claims from 2006-2010, which drops off in 2016. This aligns with a decline in WC-covered workers and Medicare and Medicaid SCHIP Extension Act of 2007 enforcing MSP payer rules within 18 months of passage. The majority of WC claims were	Among Medicare claims with WC as primary payer, WC paid 74% of costs to providers. Study helps to identify healthcare burden of occupational injury and illness to Medicare	Study likely undercounts work-related injuries and illnesses by only using WC to identify work-related claims.

					Summarized utilization by claim type. Summarized costs by amount paid to WC and Medicare.	found in the Carrier file (physician claims).	beneficiaries and identifies a need for more comprehensive surveillance.	

Table A3. Summary of literature for health outcomes of job lock and work arrangements.

Author(s)	Year	Title	Purpose of Study	Population / Data	Methods	Findings / Sensitivity of Methods	Conclusions	Limitations
Stroupe KT, Kinney ED, Kniesner JJ	2001	Chronic Illness and health insurance-related job lock.	To examine job duration for health-insurance job lock among workers with chronic illness, or a chronically ill family member	Job history from workers in Indiana, from 1984-1994	Data collected by phone interview and follow up surveys. Cox proportional hazard model to test the effect of health insurance on the duratoin a worker remained at a job.	For men who relied on employer for health insurance, having a chronic illness or a chronically ill family member reduced the likelihood of leaving job by 82%, compared to 70% among men who did not rely on employer for coverage (for women, this was 83% vs 73%). Both male and	Job lock impacts chronically ill workers and workers with chronically ill family members.	Study was limited by response rates.

						female workers who relied on employer for coverage remained in job longer than those who did not rely on employer for coverage.		
Dembe AE, Erickson JB, Delbos RG, et al	2005	The impact of overtime and long work hours on occupational injuries and illnesses: new evidence from the United States	To study how overtime and extended work hours impact the risk of work-related injuries and illnesses in the US	National Longitudinal Youth Survey respondents from 1987-2000	Evaluated job history, work hours, and work-related injury and illness outcome. Estimated relative risk of hours, long commute times, overtime on the outcome.	Overtime was associated with 61% increased HR vs jobs without overtime, at least 12 hour workdays had a 37% increased HR, and 60+ hours per week had a 23% increased HR.	Jobs with long working hours or overtime substantially increase the risk of a work-related injury or illness.	Self-reported outcomes, recall bias. Could not validate responses with other data.
Liljegren M, Ekberg K	2008	The longitudinal relationship between job mobility, perceived organizational justice, and health	To examine relationship between job mobility, health, and burnout	Survey of 662 Swedish civil servants	Self-reported turnover intentions, actual turnover, health, and burnout. Job mobility was categorized as non-mobile, internally and externally mobile.	Job mobility was a predictor of both health and burnout. Greater job mobility predicted better psychosocial health and less burnout (both personal and work-related burnout).	Job mobility predicted health and burnout better than health and burnout predicted job mobility.	Self-reported study exposure and outcomes.

Benjamin KL, Pransky G, Savageau JA	2008	Factors associated with retirement-related job lock in older workers with recent occupational injury	To evaluate health, work environment, and job lock among older workers with work-related injuries	Survey of workers with work-related injury	Mailed survey asked about pre- and post-injury health, work environment, and functioning, and job lock	Over half of injured workers reported job lock. No injury factors related to job lock, job lock was associated with job dissatisfaction and overall poorer health and mental function.	Job lock is common and may relate to overall health. Job lock may place workers at risk of work-related injuries.	Self-reported measures. No uninjured comparison group to compare risk of injury with job lock.
Tunceli K, Short PF, Moran JR, et al	2009	Cancer survivorship, health insurance, and employment transitions among older workers	To examine effect of employer-provided health insurance on labor force exit, reduction in hours, and job changes for older working cancer survivors	1997-2002 Penn State Cancer Survivor Study compared to workers with no cancer history in HRS, ages 55-64	Difference-in-differences estimation of extent that EPHI prevents employment transitions. "Job lock" was considered a reduction in probability of these transitions as a result of insurance.	Cancer survivors without job-related insurance were more likely to change employment, stop working, or cut back to part-time work, compared to those without cancer and job-related insurance.	Negative interaction of cancer survivorship and EPHI. Employment opportunities to cancer survivors are more constrained by health insurance requirements than for other workers. May prevent career advancement, workers less able to accommodate changes to their	Recall bias of employment at time of cancer diagnosis, not a nationally-representive sample of cancer survivors.

							health/functional status by cutting back hours.	
Wilkie R, Cifuentes M, Pransky G	2011	Exploring extensions to working life: job lock and predictors of decreasing work function in older workers	To explore changes in work limitations for workers with and without job lock, following a work-related injury	Prospective observational study, adults aged 55+	Questionnaire at baseline and 12 months asking job lock questions, pre- and post-injury work limitations	Before the injury, job lock workers had greater work limitations. After the injury, workers without job lock had greater work limitation increases, but for workers in job lock, work limitations led to greater problems returning to work.	Following an injury, job accomodations are important to moderate work limitations.	Self-reported job lock and health outcomes.
Huysse-Gaytandjieva A, Groot W, Pavlova M	2013	Why do some employees fall into and fail to exit a job-lock situation?	To compare those who remain in job lock to those who 1) adjust and become satisfied in same job, 2) change jobs and become satisfied, and 3) change jobs and remain dissatisfied	1991-1996 British Household Panel Survey	Job lock was measured as job dissatisfaction for two years, and remaining in job. Compared satisfaction measures to job transitions to develop other categories.	Older, married, full-time, region with high unemployment, craft occupations and government sector jobs were more likely to enter job lock. Mental health problems, personality effect probability of remaining in	Individual differences exist in adaption to job lock, predict why those remain in or exit the situation.	Self-reported measures. Study did not differentiate voluntary and involuntary job mobility.

						job lock. Protective factors were managerial or service occupations, private sector jobs, and having promotion opportunities.		
Weaver MD, Patterson PD, Fabio A, et al	2015	The association between weekly work hours, crew familiarity, and occupational injury and illness in emergency medical services workers	To investigate whether weekly work hours increased the risk of work-related injury among EMS workers	Convenience sample of occupational injury and illness report, work schedules from 14 EMS agencies, covering a period of 1-3 years	Retrospective cohort study of 4382 EMS workers. Reviewed OSHA 300 logs from agencies to confirm work-related injuries, and abstracted work hours from schedules. Ran logistic regression models using work-related injury/illness as a binary outcome.	Part-time status and night shift work was protective against the outcome.	Extended weekly hours did not increase risk of occupational injury/illness, although part-time and night shifts were protective against the outcomes, possibly by reduced exposure to hazards during the shift.	Study lacked information on confounders, may have missed shifts workers took with other agencies outside of the study. OSHA 300 logs likely underestimat e the burden of the outcome.
Besen E, Young AE, Pransky G	2015	Exploring the relationship between age and tenure	To assess relationships between age, tenure, and	2008-2012 long-term disability claims data from a large	Measured length of disability in days, censored at	Non-linear relationship between tenure and disability, interaction with	Length of disability has a relationship with job tenure, but	Could not examine cause of interaction with age.

		with length of disability	length of disability	private insurer	365 days. Gender, hours worked per week, income, marital status, physical job demands, industry, diagnosis, and duration of short-term disability benefits were examined as covariates. Used random effects models to estimate age and tenure with length of disability.	age. At age 30, predicted length of disability was 42.3 days at 1 year tenure vs 41.5 days at 10 years tenure. At age 65, length was 56.7 days at one year and 58.5 days at 15 years. Shortest predicted length was the youngest workers with highest tenure. Longest predicted length was oldest workers with highest tenure.	differences exist across age. Age has a stronger relationship with disability than tenure, but length of disability still varies with tenure.	Length of disability benefits was outcome, but did not have return to work data.
Fisher GG, Ryan LH, Sonnega A	2016	Job Lock, Work, and Psychological Well-being in the United States	To examine associations between job lock and psychological wellbeing among older workers at Social Security retirement age	MTurk online survey. 2008 and 2010 HRS survey	Tested job lock constructs with an online survey. Used HRS financial and health insurance job lock questions. Tested hypotheses between job lock and life satisfaction	Financial job lock was associated with lower life satisfaction two years later, but health insurance job lock had mixed results.	Job lock is common among workers in the US and is related to life satisfaction. It is important to distinguish between financial and health insurance job lock as they may have	Self-reported outcomes. Limited yes/no measure of job lock. Only measured life satisfaction, did not cover other measures of worker psychological wellbeing.

					using HRS data for workers age 62-65.		different associations with worker wellbeing.	
Wong CM, Tetrick LE	2017	Job crafting: Older workers' mechanism for maintaining person-job fit	To answer how job crafting will help older workers achieve greater job fit as they move forward in their careers.	Conceptual paper	Conceptual paper	Cognitive, physical, emotional, and motivational changes occur with age and in regard to work. Jobs may become more demanding as workers advance in their careers. Job crafting is the changing of boundaries and conditions of job tasks, work relationships, and overall meaning of the job. Workers become active participants in changing their job design.	As workers age, there is greater chance of misfit with a job. Person-job misfit increases with changing job demands that are less suitable for older workers. Job crafting is an individualized process to help workers realign themselves with work and exercise personal agency to improve their job fit.	Conceptual paper
Ryan LH, Newton NJ, Chauhan PK, et al	2017	Effects of Pre-Retirement Personality, Health and Job Lock on Post-Retirement	To test whether pre-retirement personality and pre-retirement job lock affect well being in retirement.	2008 and 2010 HRS respondents	Job lock measured by self report, asking if respondent would like to leave work,	Post-retirement wellbeing outcome known as "experienced positive affect" was significantly associated with	Both pre-retirement personality and health should be considered when	Does not measure circumstances of retirement. Limitations of self reported

		Subjective Well-being			but plan to keep working for month or health insurance. Personality measured from scale questions, and subjective wellbeing measured from psychosocial questionnaire	job lock, for those with low conscientiousness on the personality scale. Subjective health, pre-retirement personality associated with post-retirement wellbeing.	evaluating the retirement transition.	exposure and outcome.
Scott KA, Fisher GG, Barón AE, et al	2018	The Associations Between Falls, Fall Injuries, and Labor Market Outcomes Among U.S. Workers 65 Years and Older:	To examine whether falls impact labor force exit or time to work limitation for older workers.	2002-2010 HRS data, adults aged 65 and older and working in at least one HRS wave	Self-reported fall requiring medical treatment. Outcomes were first report of a health-related work limitation, and time to labor force exit. Cox proportional hazards model to estimate HR.	Frequency and severity of falls was associated with health-related work limitation and time to labor force exit.	Fall prevention efforts may benefit workers to help them continue in the workforce.	Self-reported study exposure and outcomes. Small number of outcome, especially stratified by demographics.
Friedman LS, Almberg KS, Cohen RA	2019	Injuries associated with long working hours among employees in	To identify risk factors of long working hour injuries and whether long working hour	1983-2015 US Mine Safety and Health Administratio	Workers divided into four groups by time when incident occurred (2	9.6% of injuries occurred during long working hours, ranging from 5.5% in 1983 to a peak	Lack of routine, being new at the mine, specific mining activities	Data on cumulative long work hours were not available, workers may

		the US mining industry: risk factors and adverse outcomes	incidents were associated with fatalities or injuries to multiple workers in the mining industry	n Part 50 reports	hours, 2-6, 7-8, 9+). Multivariable logistic regression models to evaluate predictors of long working hour injuries relative to injuries in the first 8 hours. Modeled 9+ hours against fatal and multiple worker incidents.	of 13.9% in 2015. Irregular shift starts, newly employed, contractor employment, associated with injuries in long working hours. Long working hour injuries had higher odds of death and multiple worker injuries.	were related to long working hour injuries. Problems will continue as shift occurs toward contract labor and extended workdays in the mining industry.	have had a long shift but did not necessarily exceed a 40-hour work week. Underreporting of injuries is common. Changes have occurred in practices from 1983-2015, the year of injury was a significant predictor in the models.
Kramer A, Cho S, Gajendran RS	2020	12-Year longitudinal study linking within-person changes in work and family transitions and workplace injury risk	To explore whether within-person changes in 1) work hours, 2) from irregular to regular shift work, 3) income and spousal income, 4) spousal working hours, and 5) number of children in home relate to	National Longitudinal Youth Survey respondents from 1988-2000, age 23-43 at time of survey	Work hours, irregular shift, weekly work hours for self and spouse, income and spousal income, and number of children were self reported. Asked if had any work-related injury or illness since last interview.	Within-person changes in work hours, spousal work hours, income and number of children increased likelihood of having a work-related injury	Within-person longitudinal approach has benefits over cross-sectional, between-person studies by examining whether likelihood of an injury changes for the same	Self-reported study measures. Injuries were limited to a binary outcome, unable to compare differences in injuries or severity. Unable to determine causes or mechanisms

			the probability of having a work-related injury		Ran multilevel logistic regression, using repeated measures from the longitudinal data.		person over time, with changes to life circumstances.	of life changes.
Garthe N, Hasselhorn HM	2021	Leaving and staying with the employer-Changes in work, health, and work ability among older workers	To compare employer changes among older workers with psychosocial work factors, health, and work ability.	2014-2018 data from German cohort study, those born from 1959-1965, 2811 workers	Divided workers into enthusiastic leavers (EL), reluctant leavers (RL), enthusiastic stayers (ES), and reluctant stayers (RS) based on employment change questions. Self-reported physical and mental health, Work Ability Index, and psychosocial questionnaires were used. Analyzed by GLM repeated measures ANOVA across t1 and t2.	EL improved in health and work ability outcomes following the change. RS had poor outcomes at t1, continued to worsen by staying.	Employer changes are generally followed by improvements to work, health, and work ability. Older workers benefit from inclusive labor market policies allowing for job mobility.	May not be generalizable to US. Did not include those who became unemployed. Self-reported study measures.

Frazier C, Brown TH	2022	Work-Related Stress, Psychosocial Resources, and Insomnia Symptoms Among Older Black Workers	To examine job lock and job stress appraisal, and associations with insomnia symptoms among older Black workers.	Black workers aged 51 and older from HRS 2014 and 2016 data	Ordinary Least Squares regression. Financial and health insurance job lock questions from HRS survey, and job stress scale. Insomnia symptoms questionnaire.	Financial job lock and job stress were associated with increased insomnia symptoms.	Work-related stress is related to poor sleep among older Black workers.	Cross-sectional analysis, self-reported study measures. Does not consider specific work-related stressors.

Table A4. List and description of work-related ICD-10-CM codes.

ICD-10-CM code	Work-related codes from [1] Bush AM, Bunn TL, Liford M. Identification of work-related injury emergency department visits using International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) codes. *Inj Prev* 2021;**27**:i3–8. doi:10.1136/injuryprev-2019-043507
Y990	Civilian activity done for income or pay
Y93K3	Activity, grooming and shearing an animal
Y93K2	Activity, milking an animal
Y93H9	Activity, other involving exterior property and land maintenance, building and construction
Y93H3	Activity, building and construction
Y9381	Activity, refereeing a sports activity
Y9286	Slaughter house as the place of occurrence of the external cause
Y927	Farm as the place of occurrence of the external cause
Y926	Industrial and construction area as the place of occurrence of the external cause
Y389X1	Terrorism, secondary effects, public safety official injured
Y38891	Terrorism involving other means, public safety official injured
Y38811	Terrorism involving suicide bomber, public safety official injured
Y387X1	Terrorism involving chemical weapons, public safety official injured
Y386X1	Terrorism involving biological weapons, public safety official injured
Y385X1	Terrorism involving nuclear weapons, public safety official injured
Y384X1	Terrorism involving firearms, public safety official injured
Y383X1	Terrorism involving fires, conflagration and hot substances, public safety official injured
Y382X1	Terrorism involving other explosions and fragments, public safety official injured

Y381X1	Terrorism involving destruction of aircraft, public safety official injured
Y380X1	Terrorism involving explosion of marine weapons, public safety official injured
Y3591	Legal intervention, means unspecified, law enforcement official injured
Y35891	Legal intervention involving other specified means, law enforcement official injured
Y35811	Legal intervention involving manhandling, law enforcement official injured
Y35491	Legal intervention involving other sharp objects, law enforcement official injured
Y35411	Legal intervention involving bayonet, law enforcement official injured
Y35401	Legal intervention involving unspecified sharp objects, law enforcement official injured
Y35391	Legal intervention involving other blunt objects, law enforcement official injured
Y35311	Legal intervention involving baton, law enforcement official injured
Y35301	Legal intervention involving unspecified blunt objects, law enforcement official injured
Y35291	Legal intervention involving other gas, law enforcement official injured
Y35211	Legal intervention involving injury by tear gas, law enforcement official injured
Y35201	Legal intervention involving unspecified gas, law enforcement official injured
Y35191	Legal intervention involving other explosives, law enforcement official injured
Y35121	Legal intervention involving injury by explosive shell, law enforcement official injured
Y35111	Legal intervention involving injury by dynamite, law enforcement official injured
Y35101	Legal intervention involving unspecified explosives, law enforcement official injured
Y35091	Legal intervention involving other firearm discharge, law enforcement official injured
Y35041	Legal intervention involving injury by rubber bullet, law enforcement official injured
Y35031	Legal intervention involving injury by rifle pellet, law enforcement official injured
Y35021	Legal intervention involving injury by handgun, law enforcement official injured
Y35011	Legal intervention involving injury by machine gun, law enforcement official injured
Y35001	Legal intervention involving unspecified firearm discharge, law enforcement official injured
W890	Exposure to welding light

W861	Exposure to industrial wiring, appliances and electrical machinery
W408	Explosion of other specified explosive materials (explosion in dump/factory/grain store munitions)
W400	Explosion of blasting materials
W363	Explosion and rupture of pressurized-gas tank
W35	Explosion and rupture of boiler
W3183	Contact with special construction vehicle in stationary use
W3182	Contact with other commercial machinery (commercial electric fans, commercial kitchen appliances)
W313	Contact with prime movers (gas turbine, steam engine)
W310	Contact with mining and earth-drilling machinery
W309	Contact with unspecified agricultural machinery
W308	Contact with other specified agricultural machinery
W303	Contact with grain storage elevator
W302	Contact with hay derrick
W301	Contact with power take-off devices
W300	Contact with combine harvester
W30	Contact with agricultural machinery
W12	Fall on and or from scaffolding
V8651	Driver of ambulance or fire engine injured in nontraffic accident
V8601	Driver of ambulance or fire engine injured in traffic accident
V856	Passenger of special construction vehicle injured in nontraffic accident
V855	Driver of special construction vehicle injured in nontraffic accident
V854	Person injured while boarding or alighting from special construction vehicle
V851	Passenger of special construction vehicle injured in traffic accident
V850	Driver of special construction vehicle injured in traffic accident
V846	Passenger of special agricultural vehicle injured in nontraffic accident

V845	Driver of special agricultural vehicle injured in nontraffic accident
V844	Person injured while boarding or alighting from special agricultural vehicle
V841	Passenger of special agricultural vehicle injured in traffic accident
V840	Driver of special agricultural vehicle injured in traffic accident
V84	Occupant of special vehicle mainly used in agricultural injured in accident
V836	Passenger of special industrial vehicle injured in nontraffic accident, includes battery-powered airport passenger vehicle, battery-powered truck (baggage) (mail), coal-car in mine, forklift (truck), logging car, self- propelled industrial truck, station baggage truck (powered), tram, truck, or tub in mine or quarry
V835	Driver of special industrial vehicle injured in nontraffic accident, includes battery-powered airport passenger vehicle, battery-powered truck (baggage) (mail), coal-car in mine, forklift (truck), logging car, self-propelled industrial truck, station baggage truck (powered), tram, truck, or tub in mine or quarry
V834	Person injured while boarding or alighting from special industrial vehicle, includes battery-powered airport passenger vehicle, battery-powered truck (baggage) (mail), coal-car in mine, forklift (truck), logging car, self-propelled industrial truck, station baggage truck (powered), tram, truck, or tub in mine or quarry
V831	Passenger of special industrial vehicle injured in traffic accident, includes battery-powered airport passenger vehicle, battery-powered truck (baggage) (mail), coal-car in mine, forklift (truck), logging car, self-propelled industrial truck, station baggage truck (powered), tram, truck, or tub in mine or quarry
V830	Driver of special industrial vehicle injured in traffic accident, includes battery-powered airport passenger vehicle, battery-powered truck (baggage) (mail), coal-car in mine, forklift (truck), logging car, self-propelled industrial truck, station baggage truck (powered), tram, truck, or tub in mine or quarry
V794	Driver of bus injured in collision with other and unspecified motor vehicles in traffic accident
V790	Driver of bus injured in collision with other and unspecified motor vehicles in nontraffic accident
V785	Driver of bus injured in noncollision transport accident in traffic accident
V780	Driver of bus injured in noncollision transport accident in nontraffic accident
V775	Driver of bus injured in collision with fixed or stationary object in traffic accident
V770	Driver of bus injured in collision with fixed or stationary object in nontraffic accident
V765	Driver of bus injured in collision with other nonmotor vehicle in traffic accident
V760	Driver of bus injured in collision with other nonmotor vehicle in nontraffic accident

V755	Driver of bus injured in collision with railway or train or railway vehicle in traffic accident
V750	Driver of bus injured in collision with railway or train or railway vehicle in nontraffic accident
V745	Driver of bus injured in collision with heavy transport vehicle or bus in traffic accident
V740	Driver of bus injured in collision with heavy transport vehicle or bus in nontraffic accident
V735	Driver of bus injured in collision with car, pick-up truck or van in traffic accident
V730	Driver of bus injured in collision with car, pick-up truck or van in nontraffic accident
V725	Driver of bus injured in collision with two-or three- wheeled motor vehicle in traffic accident
V720	Driver of bus injured in collision with two-or three- wheeled motor vehicle in nontraffic accident
V715	Driver of bus injured in collision with pedal cycle in traffic accident
V710	Driver of bus injured in collision with pedal cycle in nontraffic accident
V705	Driver of bus injured in collision with pedestrian or animal in traffic accident
V700	Driver of bus injured in collision with pedestrian or animal in nontraffic accident
V695	Passenger in heavy transport vehicle injured in collision with other and unspecified motor vehicles in traffic accident
V694	Driver of heavy transport vehicle injured in collision with other and unspecified motor vehicles in traffic accident
V690	Driver of heavy transport vehicle injured in collision with other and unspecified motor vehicles in nontraffic accident
V685	Driver of heavy transport vehicle injured in noncollision transport accident in traffic accident
V680	Driver of heavy transport vehicle injured in noncollision transport accident in nontraffic accident
V675	Driver of heavy transport vehicle injured in collision with fixed or stationary object in traffic accident
V670	Driver of heavy transport vehicle injured in collision with fixed or stationary object in nontraffic accident
V665	Driver of heavy transport vehicle injured in collision with other nonmotor vehicle in traffic accident
V660	Driver of heavy transport vehicle injured in collision with other nonmotor vehicle in nontraffic accident
V655	Driver of heavy transport vehicle injured in collision with railway train or railway vehicle in traffic accident
V650	Driver of heavy transport vehicle injured in collision with railway train or railway vehicle in nontraffic accident
V645	Driver of heavy transport vehicle injured in collision with heavy transport vehicle or bus in traffic accident

V640	Driver of heavy transport vehicle injured in collision with heavy transport vehicle or bus in nontraffic accident
V635	Driver of heavy transport vehicle injured in collision with car, pick-up truck or van in traffic accident
V630	Driver of heavy transport vehicle injured in collision with car, pick-up truck or van in nontraffic accident
V625	Driver of heavy transport vehicle injured in collision with two- or three-wheeled motor vehicle in nontraffic accident
V620	Driver of heavy transport vehicle injured in collision with two- or three-wheeled motor vehicle in nontraffic accident
V615	Driver of heavy transport vehicle injured in collision with pedal cycle in traffic accident
V610	Driver of heavy transport vehicle injured in collision with pedal cycle in nontraffic accident
V605	Driver of heavy transport vehicle injured in collision with pedestrian or animal in traffic accident
V600	Driver of heavy transport vehicle injured in collision with pedestrian or animal in nontraffic accident
T704	Effects of high-pressure fluids (hydraulic, pneumatic, traumatic jet injection (industrial))

Table A5. List and description of work-related agricultural ICD-10-CM codes.

ICD-10-CM code	Work-related agricultural codes from Scott E, Hirabayashi L, Graham J, et al. Using hospitalization data for injury surveillance in agriculture, forestry and fishing: a crosswalk between ICD10CM external cause of injury coding and The Occupational Injury and Illness Classification System. Injury Epidemiology 2021;8:6. doi:10.1186/s40621-021-00300-6
Y93K9	Activity, other involving animal care
Y93K3	Activity, grooming and shearing an animal
Y93K2	Activity, milking an animal
Y9279	Other farm location as the place of occurrence of the external cause
Y9274	Orchard as the place of occurrence of the external cause
Y9273	Farm field as the place of occurrence of the external cause
Y9272	Chicken coop as the place of occurrence of the external cause
Y9271	Barn as the place of occurrence of the external cause
W309XXS	Contact with unspecified agricultural machinery, sequela
W309XXD	Contact with unspecified agricultural machinery, subsequent encounter
W309XXA	Contact with unspecified agricultural machinery, initial encounter
W3089XS	Contact with other specified agricultural machinery, sequela
W3089XD	Contact with other specified agricultural machinery, subsequent encounter
W3089XA	Contact with other specified agricultural machinery, initial encounter
W3081XS	Contact with agricultural transport vehicle in stationary use, sequela
W3081XD	Contact with agricultural transport vehicle in stationary use, subsequent encounter
W3081XA	Contact with agricultural transport vehicle in stationary use, initial encounter
W303XXS	Contact with grain storage elevator, sequela

W303XXD	Contact with grain storage elevator, subsequent encounter
W303XXA	Contact with grain storage elevator, initial encounter
W302XXS	Contact with hay derrick, sequela
W302XXD	Contact with hay derrick, subsequent encounter
W302XXA	Contact with hay derrick, initial encounter
W301XXS	Contact with power take-off devices (PTO), sequela
W301XXD	Contact with power take-off devices (PTO), subsequent encounter
W301XXA	Contact with power take-off devices (PTO), initial encounter
W300XXS	Contact with combine harvester, sequela
W300XXD	Contact with combine harvester, subsequent encounter
W300XXA	Contact with combine harvester, initial encounter
V849XXS	Unspecified occupant of special agricultural vehicle injured in nontraffic accident, sequela
V849XXD	Unspecified occupant of special agricultural vehicle injured in nontraffic accident, subsequent encounter
V849XXA	Unspecified occupant of special agricultural vehicle injured in nontraffic accident, initial encounter
V847XXS	Person on outside of special agricultural vehicle injured in nontraffic accident, sequela
V847XXD	Person on outside of special agricultural vehicle injured in nontraffic accident, subsequent encounter
V847XXA	Person on outside of special agricultural vehicle injured in nontraffic accident, initial encounter
V846XXS	Passenger of special agricultural vehicle injured in nontraffic accident, sequela
V846XXD	Passenger of special agricultural vehicle injured in nontraffic accident, subsequent encounter
V846XXA	Passenger of special agricultural vehicle injured in nontraffic accident, initial encounter
V845XXS	Driver of special agricultural vehicle injured in nontraffic accident, sequela
V845XXD	Driver of special agricultural vehicle injured in nontraffic accident, subsequent encounter
V845XXA	Driver of special agricultural vehicle injured in nontraffic accident, initial encounter
V844XXS	Person injured while boarding or alighting from special agricultural vehicle, sequela
V844XXD	Person injured while boarding or alighting from special agricultural vehicle, subsequent encounter

V844XXA	Person injured while boarding or alighting from special agricultural vehicle, initial encounter
V843XXS	Unspecified occupant of special agricultural vehicle injured in traffic accident, sequela
V843XXD	Unspecified occupant of special agricultural vehicle injured in traffic accident, subsequent encounter
V843XXA	Unspecified occupant of special agricultural vehicle injured in traffic accident, initial encounter
V842XXS	Person on outside of special agricultural vehicle injured in traffic accident, sequela
V842XXD	Person on outside of special agricultural vehicle injured in traffic accident, subsequent encounter
V842XXA	Person on outside of special agricultural vehicle injured in traffic accident, initial encounter
V841XXS	Passenger of special agricultural vehicle injured in traffic accident, sequela
V841XXD	Passenger of special agricultural vehicle injured in traffic accident, subsequent encounter
V841XXA	Passenger of special agricultural vehicle injured in traffic accident, initial encounter
V840XXS	Driver of special agricultural vehicle injured in traffic accident, sequela
V840XXD	Driver of special agricultural vehicle injured in traffic accident, subsequent encounter
V840XXA	Driver of special agricultural vehicle injured in traffic accident, initial encounter