

THESIS

THE ROLE OF AGING ON THE CAUSE, TYPE AND COST OF  
CONSTRUCTION INJURIES

Submitted by

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## ABSTRACT

### THE ROLE OF AGING ON THE CAUSE, TYPE AND COST OF CONSTRUCTION INJURIES

As older workers continue to delay retirement, understanding the health and safety needs of an aging workforce will be critical over the next twenty years. The goal of the project was to determine the impact of age on workers in the construction industry as age relates to selected workers' compensation variables. Descriptive and multivariate analysis of over one hundred thousand workers' compensation construction industry claims for the state of Colorado was conducted to understand the relationship between the claimant age and workers' compensation costs by the causes and types of injuries and illnesses. The results indicated that the cost of injuries among older workers was greatest for indemnity costs alone, where there was a 3.5% increase in the indemnity cost of a claim for each year increase in age. Workers over the age of 65 were injured most frequently from falls, slips and trips and workers aged 35 to 64 were injured most frequently from strains. Though repetitive motion causes of injuries were not frequent among all age groups, they resulted in a 6.8% increase in the indemnity cost of a claim for each year increase in age. Strains were the most common type of injury for workers over the age of 35 but workers over the age of 65 experienced strains and contusions at similar frequencies. The shift towards an older work force will result in an increase in the proportion of occupational injuries among older workers, which will result in increased costs associated with

lost work time and disability. Employers who wish to remain competitive must effectively manage a health and safety program that acknowledges the needs of the aging worker.

Encouraging companies to address the specific needs of older workers is the first step in reducing the frequency and cost of occupational injuries related to older age.

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## Introduction

The enormous birth cohort born between 1946 and 1964 combined with the collapse of financial markets and an economic recession during the first decade of the 21<sup>st</sup> century have led to an increase in the proportion of older workers in the US workplace. The 20<sup>th</sup> century trend towards earlier retirement has reversed and growing numbers of employees are planning for longer working careers (Shuford & Restrepo, 2005; Silverstein, 2008). As older workers continue to delay retirement, understanding the health and safety needs of an aging workforce will be critical over the next twenty years. Working in the 5<sup>th</sup>, 6<sup>th</sup>, and even the 7<sup>th</sup> decade of life may be even more significant in terms of injuries for workers involved in traditionally high risk and physically demanding occupations such as the construction industry. Employers that promote and support the workability of aging employees will gain skilled and productive employees by providing safe, productive, competitive, and sustainable business practices (Silverstein, 2008).

Aging is associated with reduced physical capacities in strength, balance, and processing speed. Thus, it is logical to assume that aging may be associated with a degradation in physical and mental performance and higher rates of injury (Maertens, Putter, Chen, Diehl, & Huang, in press). Research on workers' compensation claims, however, indicates that older workers typically have lower rates of workplace injuries but their injuries are associated with higher costs (Shuford & Restrepo, 2005; WCRI, 2002). However, there is little research that has examined the nature and cause of injuries among older workers, especially those in their late 50s and 60s (Shuford & Restrepo, 2005).

Despite the increased awareness and research related to construction workers health and safety over the last twenty years, the construction industry remains one of the most dangerous industries in the US (Choi, 2009). Injury trends among vulnerable workers, such as the growing

number of older workers need to be studied within the construction industry to assist in targeting specific interventions aimed at helping older workers stay employed and preventing age and work-related injuries (Schoenfisch, Lipscomb, Shishlov, & Myers, 2010; Kisner & Fosbroke, 1994). There are no published studies specifically investigating age-related trends among a large cohort of workers in the construction trade that report the nature, cause, and costs of work-related injuries. This study is the first comprehensive effort that identifies age-related trends associated with compensation claim variables of type and cause of injuries and their related costs.

The goal of the project was to determine the impact of age on workers in the construction industry as age relates to selected worker compensation variables. The investigators of this project acquired a database of workers' compensation claims from Pinnacol Assurance, the provider of workers' compensation coverage for nearly 80% of Colorado construction companies. The database included approximately 111,000 claims filed during the 10-year period from June 30, 1998 and June 30, 2008. The claims data were analyzed to determine the influence of age on cost (total, medical and indemnity), cause of injury and type of injury. Total cost of a claim included all direct medical expenses, indemnity costs and all other miscellaneous expenses such as legal fees. Medical costs include all medical bills paid by the workers' compensation company. Indemnity costs include wage replacement, disability and death benefits. Cause of injury was defined as the method by which the claimant was injured (e.g., burn). Injury type was defined as the type of injury sustained by the claimant (e.g., cut).

The goal of the project was consistent with the National Occupational Research Agenda (NORA) Construction Strategic Goal 12.0: To reduce injuries and illnesses among groups of construction workers through improved understanding of why some groups of workers

experience disproportionate risks in construction work. More specifically, the proposed study addressed the NORA construction intermediate goal 12.2, which states that an improved understanding of conditions and factors that contribute to disproportionate risk and the mechanisms through which vulnerability places workers at increased risk for work-related injury in the construction trades and their longitudinal effects is needed. This study addressed this intermediate goal by addressing the research goal 12.2.4, which notes age-related injury and illness characteristics that need to be identified (NIOSH, 2009). Priority topics for future construction research as identified by the Construction Sector Council in 2002 included a focus on subpopulations such as aging workers. It is also consistent with the Center for Construction Research and Training (CPWR) goal of focusing on emerging issues.

### **Specific Aims of Study**

1. Determine the relationship between age and cost of injury associated with occupational related injuries and illnesses.
  1. Hypothesis 1: The cost (total, medical and indemnity) of claims will increase with increasing age of claimant.
2. Determine the relationship between causes of injuries and illnesses and cost by age.
  1. Hypothesis 2a: There will be differences in the frequency distribution of causes by age of claimant.
  2. Hypothesis 2b: There will be differences in the relationship between causes and cost (total, medical, and indemnity) by age of claimant.
3. Determine the relationship between the type of injuries and illnesses and cost by age.
  1. Hypothesis 3a: There will be differences in the frequency distribution of types of injuries by age of claimant.

2. Hypothesis 3b: There will be differences in the relationship between types of injuries and illnesses and cost (total, medical, and indemnity) by age of claimant.

## **Literature Review**

### **Aging and work**

There is no consensus on the age at which a worker becomes classified as an older worker. However, it is clear that the number of adults continuing to work later in life is rising. The number of US workers who are 55 years and older will increase by nearly 50% from 2004 to 2014. The proportion of workers 55 and over relative to all workers is also growing, from 11.9% in 1994, 15.6% in 2004, to an expected 21.2% in 2014 (Toossi, 2005). According to an analysis of the Health and Retirement Study, the reasons for increases in the retirement age are: decreases in social security benefits, diminishing value of private pension portfolios, and increasing health and longevity (Cahill, Giandrea, & Quinn, 2005).

Prior to mid-1980 there were incentives to retire early. Retirement became a planned phase of life in the early 1900's that was encouraged by the government and private sector. The Social Security Act of 1935 legislated a social insurance program that provided income for retired workers over the age of 65. Then in 1961, the age requirement was lowered to 62. Corporate pension plans were designed to compliment Social Security and only had to offer benefits for a short time period since the average life expectancy was about 70.2 years in 1961 (Ezzati, Friedman, Kulkarni, & Murray, 2008; Hedge, Borman, & Lammlein, 2006). Such plans also encouraged early retirement, sometimes as early as 55 years of age (Wiatrowski, 2001).

In the past few decades, however, retirement age has become less defined. Legislative changes enabled older workers to continue to work without penalties. The Age Discrimination in Employment Act of 1986 eliminated mandatory retirement. The Pension protection act of

2006 has made it easier for older workers to receive pension benefits while still working. Older workers were also encouraged to stay on the job longer in order to account for the slowing rates of youth entering the workforce (Silverstein, 2008).

Delaying retirement has also become an economic necessity. Defined contribution retirement plans have become more popular than defined-benefit plans. Thus, workers are encouraged to stay on the job longer in order to maximize retirement benefits. Older workers may also stay on the job longer in order to replenish their retirement savings that was depleted during the financial crisis (Toossi, 2009). However, many older workers have no means of retirement support other than Social Security (Weller, 2005).

Demographic changes will reduce the ability of future generations to rely on Social Security for retirement. Social Security depends on a “pay-as-you-go” system, where the working generation pays for the costs of the retired generation. As the retired population grows, more contributions are needed to fund the program (Altman & Shactman, 2002). The Social Security system has been sustained for decades because the proportion of those in the workforce was greater than those in retirement. Yet, as the baby boomer generation (e.g. those born between 1946 and 1964) continues to retire, this trend will reverse. For example, in 1976, the proportion of youths aged 16 to 24 years in the population peaked at 22.9% but by 2008 their proportion of the population decreased to 16% and is projected to decrease to 15% by 2018 (Toossi, 2009). Thus, the small number of younger workers cannot generate the money needed to sustain the increasing number of baby boomers retiring. Altman and Shactman (2005) compare this problem to a corporation that promised benefits to retired workers but has not set aside the funds to pay the benefits (p. 4). Baby boomers that enabled the success of Social

Security prior to 1980 will not be able to receive the same retirement benefits in the years to come.

Those in poor health, without sufficient financial resources for retirement, may be forced to continue working. Maertins et al. (*in press*) note that for some older adults working is associated with sustained health and wellness yet for others “changing physical capabilities may lead to reduced occupational health functioning.” McLaughlin, Connell, Heeringa, Li and Roberts (2009) used Rowe and Kahn’s conceptualization of successful aging in order to estimate the prevalence of “successful aging” among US adults over the age of 51 in the United States using data from the Health and Retirement Study. McLaughlin et al., (2009) defined successful aging as having no major disease, no disabilities affecting daily activities, no more than one difficulty with seven measures of physical functioning, obtaining a median or higher score on tests of cognitive functioning and being “actively engaged” (p. 217). They found that in 2004 the prevalence of successful aging in the US was only 10.9%. This suggests that the aging workforce is living and working with disease and disabilities that can affect their ability to work safely. Benjamin, Pransky & Savageau (2008) contend that older workers might not be able to reduce work hours or switch to less physically demanding work without risking pension or health benefits. Thus, older workers may find themselves in a difficult situation. They will need to continue working for financial reasons, but may be unable to perform the same tasks as well as their younger counterparts.

The physiology of aging involves many physical changes that can make work tasks more difficult. Physically demanding work may be difficult due to cardiovascular changes that lead to decreased cardiac output and reduced tolerance to physical activity (Fitzgerald, Tanaka, Tran, & Seals, 1997). Older workers are also susceptible to a loss of muscle mass that contributes to

decreased strength (Thomas, 2010, p. 335). Bone density decreases with age resulting in a greater propensity for fractures (Sattelmair, Pertman, & Forman, 2009). Older adults are also susceptible to inflammation leading to arthritis and other disorders that can limit joint range of motion (Spector, et al., 1997; Strandberg & Tilvis, 2000). Body composition and weight also tend to change with age, thus predisposing workers to diabetes, hypertension, and reduced flexibility and mobility. Thus, the aging process can involve significant physical changes that challenge a worker's ability to perform work tasks without incurring injury, especially in occupations that are physically demanding.

Though older workers may experience physical limitations, their ability to add value to an organization is significant. A recent meta-analysis examined the relationship between age and several job performance measures. Ng & Feldman (2008) found that age was not significantly related to core task performance or creativity but it was significantly related to increased safety performance and decreased counterproductive work behavior. Employers who resist adapting work to older workers are susceptible to losing experienced workers and paying more in hiring and training costs (Yeatts, Folts, & Knapp, 1999). Given the dominant role older workers will play in the future, it is critical to understand how to shape work environments in order to take advantage of their talents in order to minimize the challenges they face on the job (Ng & Feldman, 2008).

### **Aging in the construction industry workforce**

The Center for Construction Research and Training reported a 70% increase in the number of paid construction workers from 1977 to 2002 (Center for Construction Research and Training, 2008). The growth of the construction industry is expected to be hindered by a

shortage of skilled workers (Goodrum, 1999), and keeping skilled workers from leaving the industry is a high priority in the United States (Welch, Haile, Boden, & Hunting, 2010).

The increasing numbers of aging workers in the construction industry follows average industry trends. Across all industries, the average age of the workforce has steadily increased from 37.3 in 1985 to 40.6 in 2005. In the construction industry, the average age of workers increases as well, but it is still younger than the across industry average. The average age was 36 in 1985 and 39.4 in 2005. As indicated previously, the increase in participation of older workers in the workforce may be explained by the low rates of younger workers entering the workforce as well as changes in the financial resources of older workers. The younger average age of workers in the construction industry, compared to all industries, may also be due to construction workers retiring earlier than the overall workforce (Center for Construction Research and Training, 2008).

Due to the nature of the trade, most construction workers experience a physically demanding work environment. The industry is characterized by long hours (Haslam, et al., 2005), task variability, irregular work periods (Forde & Buchholz, 2004), unpredictable workplaces and non-continuous employment (Ringen & Stafford, 1996). The physical demands of the job involve heavy lifting, use of vibrating tools, pulling, twisting, and bending which eventually result in injury to joints, limbs, muscles and ligaments (LeMasters, Bhattacharya, Borton, & Mayfield, 2006; Merlino, Rosecrance, Anton, & Cook, 2003; Rosecrance, Cook, & Zimmerman, 1996). Performing construction work, where multiple physical demands are present, can increase the probability of injury (Choi, 2009).

The cause and type of injuries in the construction industry has been found to differ by the age of worker, but details of the relationship between injuries and age are not well known (e.g.,



Haslam et al., 2005; Schoenfisch et al., 2010). For example, information on the cause of injuries among workers in their 60's is minimal. Previous research on age-related trends in the construction industry has found that older workers are more susceptible to more severe injuries than younger workers, but the data was limited in scope by trade and injury type (Welch, Haile, Boden, & Hunting, 2008; Welch, et al., 2010).

Injuries are less frequent but more severe among older construction workers.

Schoenfisch et al. (2010) found that the proportion of injuries treated at the emergency rooms decreased with age. Hoonakker & van Duivenbooden (2010) also found that older Dutch construction workers were less likely to be injured than younger workers. While injury rates may be lower among older workers, time to recovery and injury costs increased with increasing age. A recent review of the literature on construction's aging workforce found that older workers sustained more severe injuries and had a longer sick leave period than younger workers (Choi, 2009). Schoenfisch et al. (2010) found that when older workers were in fact injured, the proportions treated at ERs resulting in treatment and release decreased with increasing age.

A construction worker's physical limitations may have a strong impact on the decision to retire. A longitudinal study of roofers found that the differences between workers who did not leave work and those who did were similar in age but different in the number of work limitations (Welch et al., 2008). Mayer, Gatchel & Evans (2001) found that the return to work rate after work-related spinal disorder rehabilitation significantly decreased with increasing age.

Returning to work in the construction industry is difficult because it is hard to reduce worker exposure to physically demanding work. The challenge in modifying work coupled with disability duration indicates that primary prevention is necessary in retaining experienced construction workers (Courtney, Matz, & Webster, 2002).

## **Cost of work related injuries and illnesses in the construction industry**

Given the precarious and physically challenging work conditions coupled with aging trends, it is not hard to imagine the enormous cost of injuries among older workers and the industry. Haslam et al. (2005) note, “accidents in the construction industry represent a substantial ongoing cost to employers, workers and society” (p. 402). While construction workers represent only six percent of the US workforce, they account for a disproportionate 15% of costs related to injuries and fatalities for all US industries (Waehrer, Dong, Miller, Haile, & Men, 2007). Vulnerable populations, such as older workers, contribute to much of those costs. In general, workers compensation claim costs increase with the age of workers (Friedman & Forst, 2009). For example, Lipscomb, Leiming & Dement (2003) found that costs associated with falls in construction were three times higher for those over 45 years when compared with those under 30 years of age. Lowery et al. (1998) found that lost work time increased with age, which results in increased indemnity costs. Schoenfisch et al. (2010) determined that, although older construction worker injury rates were lower than younger workers, injuries were more likely to cause more serious conditions, greater chance of disability, require more hospitalizations, and require longer recovery times.

## **Workers’ Compensation data as occupational health surveillance**

Workers’ compensation was legislated in the early 20<sup>th</sup> century to alleviate the financial consequences of occupational injuries and illnesses (Guyton, 1999). Under the exclusive remedy rule employers were free from employee lawsuits as long as the employer carried workers’ compensation insurance. At the same time, employees were guaranteed fair compensation regardless of fault. Compensation included medical costs, lost wages, and expenses incurred.

Colorado legislated workers' compensation in 1915 by creating the state compensation insurance fund, which would eventually become Pinnacol Assurance.

Workers' compensation in Colorado operates in a competitive market where multiple insurance companies are allowed to sell insurance including Pinnacol Assurance. Pinnacol Assurance is a 'carrier of last resort' insurance fund where employers who cannot purchase insurance from another carrier are able to purchase insurance from the state. They are considered to be a quasi-public insurance company enabled by a Colorado statute. Pinnacol Assurance insures 57% of all employers and approximately 80% of all construction companies in Colorado.

By state statute Pinnacol Assurance is required to write policies and provide benefits to all Colorado companies that wish to be insured by them. Pinnacol Assurance provides medical, wage-replacement, permanent impairment or disfigurement and death benefits to employees.

“Medical benefits include payment for all expenses associated with physician visits, hospital treatments, rehabilitation, diagnostic testing, and prescription medications.

Wage-replacement benefits (indemnity) include payment for lost wages, up to two thirds of the injured worker's normal earnings. An injured worker is eligible for indemnity benefits after three lost days of work due to injury (Division of Workers' Compensation, 2010).”

In order to receive benefits, an injured worker must report an injury to their employer within four days and the employer is required to notify Pinnacol Assurance within thirty days (Division of Workers' Compensation, 2010). A workers compensation claim begins with the first report of injury form, which serves as official notification to Pinnacol Assurance that a worker has been injured (a copy of the report can be found in the Appendix). Pinnacol Assurance then manages

the claim by tracking the worker's health status, paying medical bills, paying lost wages and disability benefits, and providing return work services.

Workers' compensation data have been used as a source of surveillance data that can be used to characterize occupational injuries and illnesses. The utility of workers' compensation data has been demonstrated by many studies that have characterized work related injuries in terms of their cost, type, and cause in a variety of occupations (Friedman & Forst, 2009; Hofmann, Snyder, & Keifer, 2006). Colorado workers' compensation data have been used to identify costs, characteristics and contributing factors of agricultural injuries and illnesses (Doughrate, Rosecrance, Reynolds, Stallones, & Gilkey, 2009; Doughrate, Rosecrance, Stallones, Reynolds, & Gilkey, 2009; Doughrate, Rosecrance, & Wahl, 2006). Workers compensation data have advantages over other sources of occupational surveillance data. Unlike the National Electronic Injury Surveillance System's occupational injury supplement (NEISS-Work), workers' compensation data are not limited to injuries and illnesses that require emergency room treatment. Other strengths of these data include the completeness and accuracy of the cost variables in the data. Although the Bureau of Labor Statistics publishes the most comprehensive injury and illness data, it does not provide readily accessible information on the type or cause of the injury by age for the construction industry.

Workers' compensation data have been successfully used as a method of occupational health surveillance in the past, however, its limitations should be acknowledged. Workers' compensation data are not collected for epidemiological surveillance purposes and thus are not representative all occupational injuries and illnesses (Hofmann, et al., 2006; Morse, et al., 2005). Workers may not report their injuries or illnesses due to fear of employer retribution, lack of recognition of occupational injuries by physicians, employers or workers, administrative barriers

or because alternative medical providers might have been used (Bonauto, Silverstein, Kalat, & Connon, 2003). The data may also not represent undocumented workers (Estrada, 2004). Not all those who qualify for workers' compensation benefits file a claim; studies have shown that filing rates range from 35% to 79% (Doughrate et al., 2009). When a claim is filed, filtering effects may occur where there is a loss of information between the time an injury occurs and when a claim is filed. Examples of filtering effects include: negative worker attitudes towards reporting, negative supervisor attitudes towards the injured worker, lack of supervisor training, and company policies inhibiting reporting. These filtering effects can cause injury underreporting and misreporting (Webb, Redman, Wilkinson, & Sanson-Fisher, 1989). Lastly, workers' compensation data do not include race/ethnicity, socioeconomic status, lifestyle factors (e.g., smoking history, body size, etc.), health insurance status, job-related activities, or past exposure to workplace hazards (Dembe, 2004).

## **Methods**

### **Population to be studied**

The dataset represents workers' compensation claims filed by workers in the construction trade in the state of Colorado with Pinnacol Assurance between June 30, 1998 and June 30, 2008. Claims are "open" and incur costs for a period of time following the initial injury. Thus, a 24-month duration following the initial date of injury claim was chosen to use for the analysis of cost data. The 24-month period represents a time-frame with very little (<1%) additional costs after that period (personal communication with actuarial at Pinnacol, 2010). For example, a claim that was submitted on June 30, 1998 was represented in the dataset after a period of 24 months on June 30, 2000. Thus, the data represents the cost of all claims from June 30, 2000 to June 30, 2010. A timeline of claim filing can be seen in Figure 1.



*Figure 1. Timeline of claim filing*

The dataset represented approximately 80% of all construction companies for the state of Colorado. The remaining 20% of construction companies include self-insured companies, companies who chose to be insured by another workers’ compensation insurance carrier or companies that are comprised of only owners (personal communication with Director of Risk Management at Pinnacol, 2011). The dataset also only included claims from adults, 18 years or older.

**Description of the dataset**

A dataset was created from Colorado workers’ compensation claims representing all construction trades as referenced by National Council on Compensation Insurance codes. All personal identifiers in the dataset were removed and coded with a unique claimant number before the dataset was given to the investigators. Pinnacol Assurance kept a separate file with the unique claimant numbers and names. The Institutional Review Board at the university indicated that the project was exempt from IRB since individuals within the dataset were not identifiable. All claims data was exported from Pinnacol’s database into a Microsoft Excel spreadsheet and saved on a secure jump drive that is password protected and has the ability to remotely destroy its contents if tampered with. A description of each variable that was used in the dataset to conduct the specific aims of the proposed study is listed in Table 1 and the coding scheme for the

cause and type of injury variable can be seen in the Appendix. An injury was defined as a wound or damage to the body by an event in the work environment (OSHA). An illness was defined as an abnormal condition or disorder, other than one resulting from an occupational injury, due to the work environment; they include acute and chronic illnesses/diseases that may be caused by inhalation, absorption, ingestion or direct contact (U.S. Bureau of Labor Statistics, 2006). A distribution of age at time of claim can be seen in Figure 2. All analyses were conducted using SAS PC software version 9.2.

Table 1

*Variables used in statistical analyses*

| Variable Category          | Definition   | Example            |
|----------------------------|--|--------------------|
| Type of injury and illness | Injury or illness sustained by claimant  | Sprain             |
| Cause of injury            | Method of energy transfer that caused the injury   | Fall, slip or trip |
| Total cost                 | Total amount paid per claim, or the sum of total medical, total indemnity, and total expense costs |                    |
| Total indemnity cost       | Total indemnity costs per claim  | Lost work wages    |
| Total medical cost         | Total medical costs per claim  | Surgery costs      |
| Age of claimant            | Age at time of injury  |                    |

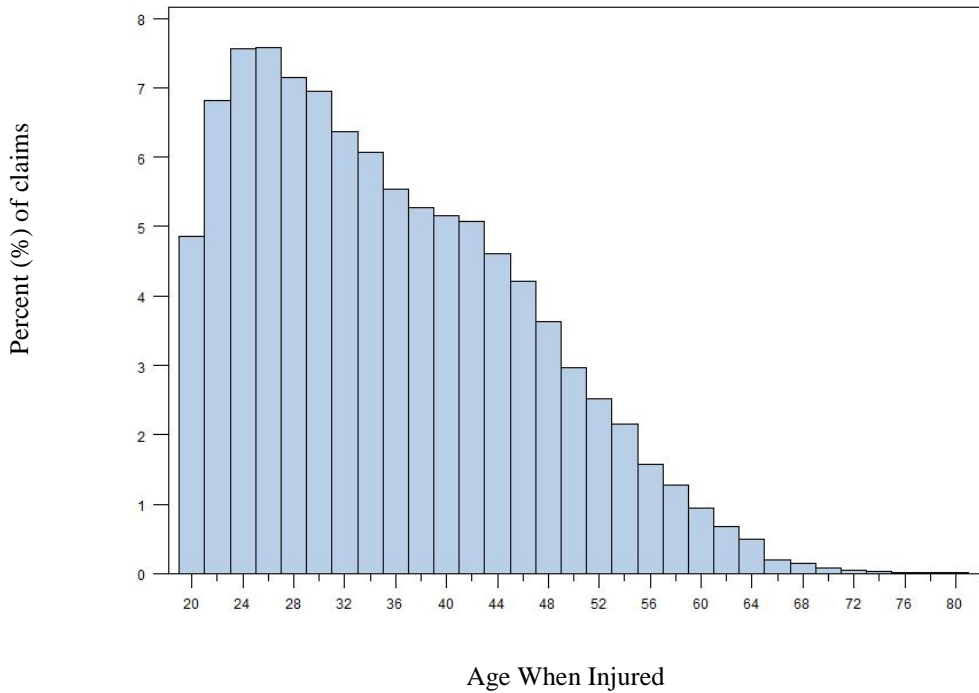


Figure 2. Age distribution at time of injury

Note. Average age: 35, SD: 10.9, Median Age: 33, IQR: 26-43, Range: 19-99,  
Total number for claims: 107,064

### Study size and statistical power

The dataset contains 107,064 individual claims for the selected 10-year period of analysis. There was more than adequate (>80%) power at  $\alpha < 0.05$  (two-sided) to detect a minimum beta coefficient of 0.009 for the relationship between the predictor variables (e.g., age, cause of injury and type of injury) and cost due to workplace injury/illness, assuming up to seven predictors in the model.

### Descriptive/Univariate analyses (for Specific Aims #1-3)

Descriptive analyses were conducted in order to understand the relationship between age of the claimant and the costs of the claim by the categories cause of injury and the types of injury (see Figure 3) by using the following steps:



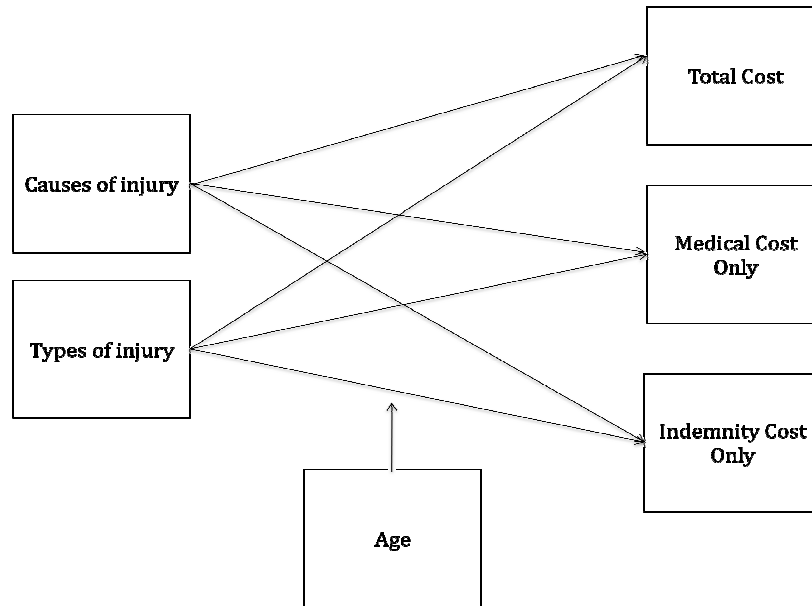


Figure3. Diagram of relationships analyzed

- (1) Evaluate distributions of outcome (total, medical, and indemnity costs) and explanatory variables (age, type of injury, and cause of injury). Age was evaluated as a continuous (years) and as a categorical variable. Log transformations of continuous variables were conducted when criteria for normality were not met. All cost variables were adjusted for inflation to the year 2010 by using the Consumer Price Index. The percent inflation depended on the year in which the claim was filed. For example, if a claim cost \$1,000 in 1998 and the percent inflation from 1998 to 2010 was 34.09%, it would have cost \$1,340 in 2010.
- (2) Assess the completeness of data for the outcome and explanatory variables, and determine whether missing values are an issue.
- (3) Plot the outcome versus the explanatory variables to identify outliers and trends in the data. Visually inspect scatter plots for continuous variables and box plots for categorical variables.

(4) Describe study population overall and by age groups for each variable. Determine the frequency and mean cost of the injury/illness cause and type of injury by age groups. Calculate Pearson correlation coefficients and corresponding *P*-values for age (years) and cost (total, medical and indemnity) (\$), and Point-bi-serial correlation coefficients (and *P*-values) for: (1) age as a continuous variable and categorical variables for: (a) cause of injury and (b) type of injury. Use analyses of variance to evaluate differences in mean cost (total cost, medical only and indemnity only) of a claim across age groups.

### **Linear regression analyses**

Linear regression methods were used to evaluate the effect of the explanatory variables (age, injury cause, and injury type) on the outcome variables (total cost, medical cost and indemnity cost). All cost variables were log-transformed in order to correct for a positively skewed distribution.

#### **The effect of age (years) on cost**

Each outcome variable (total cost, medical only and indemnity only) was assessed in separate linear regression models for the explanatory variable age of claimant (years).

#### **The interaction effects of age on the association with cost for injury cause and type**

Each outcome variable (total cost, medical only and indemnity only) was assessed by separate linear regression models for each explanatory variable of interest (cause and type of injury) and their interactions with age (years). For example, the linear regression model for total cost and cause was:

$$Y(\text{Total Cost}) = \beta_0 + \beta_1 * \text{Cause} + \beta_2 * \text{Age} + \beta_3 * \text{Cause} * \text{Age} + \varepsilon \quad (1)$$

The interaction was first assessed by determining if the Type III SS test for unequal slopes was significant for the interaction coefficient. Once the interaction between the explanatory variable and age was found to be significant, the intercept term was excluded from the models (e.g., PROC GLM model option 'noint'). For example, the linear regression model for total cost and cause was:

$$Y(\text{Total Cost}) = \beta_1 * \text{Cause} + \beta_3 \text{Cause} * \text{Age} + \varepsilon \quad (2)$$

This allowed for the direct interpretations of the interaction beta estimates as the slopes for the individual regression lines for the explanatory variables and cost by age. They represented the percent increase in the cost of a claim for the category of cause or type of injury for each year increase of age. For example, the beta estimate for falls\*age in the above model was .0124, and can be interpreted as a 1.24% increase in the cost of a claim for each year increase in age for a fall type of cause of injury.

A stepwise selection method was then used to eliminate any main effects and interaction terms that were not significant at the  $p < .0001$  level. Forward and backward selection methods were then used to confirm the stepwise selection method results.

## Results

Using workers' compensation claims data from Pinnacol Assurance, it was estimated that injured construction workers filed 111,057 claims during the ten-year period from June 30, 1998 and June 30, 2008. Of the 111,057 workers' compensation claims, those between the ages of 18 and 99 represented 107,064 claims. The mean age of a construction worker who filed a claim was 34 ( $SD=11$ ) and nearly all injured workers who filed a claim were male (95%). Age was

evaluated as a continuous variable as well as a categorical variable with the age groups: 18-24 ( $n=21,733$ ), 25-34 ( $n=36,018$ ), 35-44 ( $n=27,092$ ), 45-54 ( $n=16,360$ ), 55-64 ( $n=5,259$ ), 65+ ( $n=603$ ).

The total cost of all 107,064 claims was \$936,450,233, with a mean of \$8,697 ( $SD=$  \$37,637) and median of \$573 ( $IQR=$  \$280 - \$2,022). The total medical costs for all claims was \$411,933,676, with a mean of \$3,816 and a median of \$528. The total indemnity costs for all claims was \$462,683,499, with a mean of \$4,306 and a median of \$0. Only 22.5% ( $n=25,007$ ) of all claims filed during this time period incurred indemnity costs.

The majority of injury causes fell under two categories. Forty seven percent of all causes of injuries were attributed to strains (26.46%) and striking against or stepping on (20.18%). Falls, slips and trips (15.5%), cut, puncture or scrape (15%), and miscellaneous (13.4%) accounted for 43.96% of all causes of injuries. The remaining 9.4% of all causes of injuries were categorized as caught in, under or between (4.37%), motor vehicle (1.94%), burns (1.8%), and repetitive motion (1.29%).

The type of injuries also primarily fell under two categories. Forty eight percent of all types of injuries were attributed to strains (26.63%) and contusions (20.96%) followed by lacerations (16.55%). The remaining 35.87% of all types of injuries were accounted for by the eight remaining possible types of injuries: foreign body (7.67%), sprains (6.62%), punctures (6.46%), other (4.73%), all other (3.76%), fractures (3.61%), crushing (1.56%), and burns (1.45%). A cross-tabulation of causes and types of injuries revealed that 75.54% of the claims had strain listed as both a cause of injury as well as a type of injury.

#### **Age differences in terms of cost (Specific Aim #1)**

Pearson correlations revealed that there was a small but significant correlation between age when injured and total cost,  $r(107064)=.07, p<.0001$ , medical costs,  $r(107064)=.05, p<.0001$ , and indemnity costs,  $r(107064)=.10, p<.0001$ . Indemnity expenses were more common among older workers. For example, 33% of workers 65 years or older incurred indemnity costs where as only 18% of workers 18-24 years of age incurred indemnity costs (see Figure 4). Older workers incurred more workers' compensation costs than younger workers (see Table 2 and Figure 5).

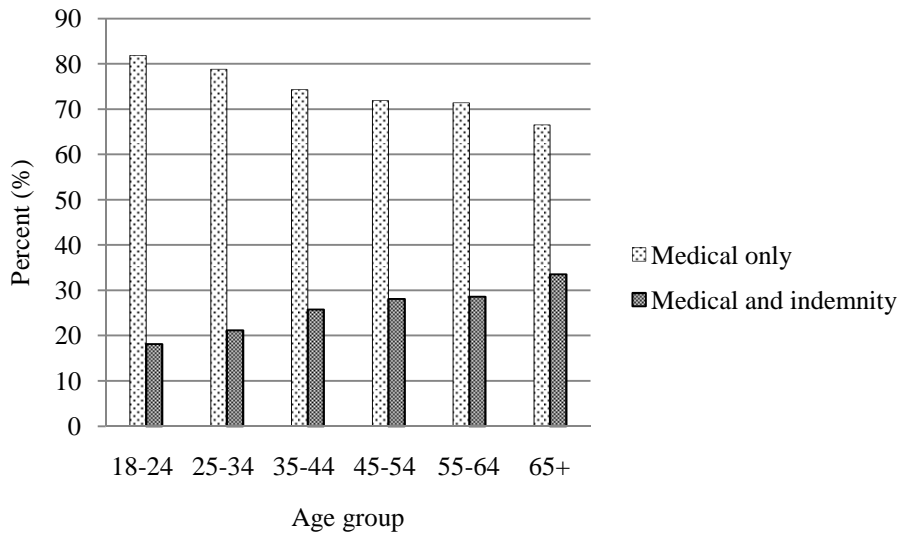


Figure 4. Claim type by age group

Table 2

*Description of workers' compensation costs by age group*

|                 | Age group                 |                           |                           |                           |                          |                      |           |
|-----------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|----------------------|-----------|
|                 | 18-24<br><i>n</i> =21,733 | 25-34<br><i>n</i> =36,018 | 35-44<br><i>n</i> =27,092 | 45-54<br><i>n</i> =16,360 | 55-64<br><i>n</i> =5,259 | 65+<br><i>n</i> =603 |           |
| Total cost (\$) | Mean                      | 4,899                     | 7,439                     | 10,320                    | 12,176                   | 13,194               | 14,253    |
|                 | (std) <sup>+</sup>        | (31,935)                  | (34,063)                  | (39,287)                  | (48,943)                 | (44,404)             | (37,170)  |
|                 | Median                    | 474                       | 544                       | 642                       | 706                      | 775                  | 861       |
| Medical (\$)    | IQR <sup>^</sup>          | 254-1,143                 | 285-1,671                 | 296-3,059                 | 305-4,707                | 308-5,464            | 295-7,056 |
|                 | Mean                      | 2,424                     | 3,284                     | 4,207                     | 5,551                    | 5,632                | 5,275     |
|                 | (std) <sup>+</sup>        | (14,026)                  | (16,665)                  | (17,387)                  | (35,944)                 | (25,971)             | (14,291)  |
| Indemnity (\$)  | Median                    | 450                       | 507                       | 582                       | 631                      | 674                  | 718       |
|                 | IQR <sup>^</sup>          | 240-963                   | 267-1,275                 | 274-1,897                 | 278-2,630                | 279-2,837            | 268-3,054 |
|                 | Mean                      | 2,168                     | 3,661                     | 5,402                     | 5,819                    | 6,762                | 8,142     |
| Indemnity (\$)  | (std) <sup>+</sup>        | (20,295)                  | (20,710)                  | (24,075)                  | (6,762)                  | (2,486)              | (25,809)  |
|                 | Median                    | 0                         | 0                         | 0                         | 0                        | 0                    | 0         |
|                 | IQR <sup>^</sup>          | 0-0                       | 0-0                       | 0-157                     | 0-690                    | 0-1,004              | 0-2,380   |

<sup>+</sup> Standard deviation

<sup>^</sup> Inter-quartile range

*Note.* Costs (\$) adjusted for inflation to 2010 dollars. Indemnity and medical costs do not add up to the total cost because expenses are not listed.

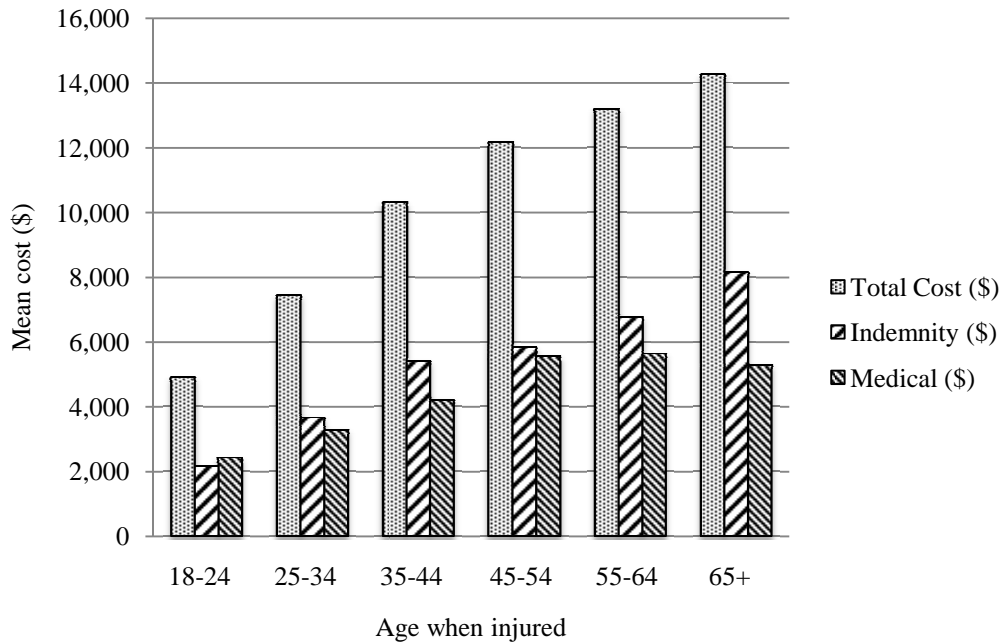


Figure 5. Mean costs of a claim by age group

One-way analyses of variance (ANOVA) were conducted to evaluate the relationship between the age groups in terms of cost (total cost, medical costs and indemnity costs) of a claim. The dependent variables (total cost, medical costs and indemnity costs) were log transformed in order to correct for non-normality and unequal variances. The ANOVA's were statistically significant for all dependent variables: total cost,  $F(5,107059) = 123.99, p < .0001$ , medical costs,  $F(5,107059) = 56.43, p < .0001$  and indemnity costs,  $F(5,107059) = 236.86, p < .0001$ . Multiple pairwise comparisons using a bonferroni adjusted alpha level of .003 per test (.05/15) revealed that there were statistically significant different mean costs between age groups, though the degree of difference varied between the three types of cost variables (see Table 3). In terms of indemnity costs only, the oldest two age groups incurred similar costs and the greatest amount of costs among all age groups. This is displayed in Table 3 by the two oldest age groups mean indemnity costs sharing the subscript "b." Mean differences in terms of medical costs only were less significant. The four oldest age groups incurred similar medical costs and workers 25-34 ( $M=434, SD=.013$ ) and 65+ ( $M=533, SD=.102$ ) did not have significantly different mean differences.

Table 3

*A priori tests of mean cost (\$) differences of a claim by age group*

|                          | Age group  |                         |                         |                         |                           |                            |
|--------------------------|------------|-------------------------|-------------------------|-------------------------|---------------------------|----------------------------|
|                          | 18-24      | 25-34                   | 35-44                   | 45-54                   | 55-64                     | 65+                        |
|                          | M (SD)     | M (SD)                  | M (SD)                  | M (SD)                  | M (SD)                    | M (SD)                     |
| Total cost (\$)          | 461 (.017) | 584 (.013)              | 729 (.015) <sub>a</sub> | 791 (.020) <sub>a</sub> | 829 (.036) <sub>a</sub>   | 933 (.106) <sub>a</sub>    |
| Medical only cost (\$)   | 365 (.016) | 434 (.013) <sub>a</sub> | 494 (.015) <sub>b</sub> | 521 (.019) <sub>b</sub> | 536 (.034) <sub>b</sub>   | 533 (.102) <sub>a, b</sub> |
| Indemnity only cost (\$) | 4 (.025)   | 6 (.019)                | 9 (.022)                | 12 (.028) <sub>a</sub>  | 13 (.050) <sub>a, b</sub> | 20 (.150) <sub>b</sub>     |

*Note.* Means in a row sharing subscripts are not significantly different from each other. All costs (\$) are adjusted for inflation to 2010 dollars. Costs were log-transformed for analysis and back-transformed into geometric means and standard deviations for ease of interpretation.

Simple linear regression analyses were conducted to determine the relationship between cost of a claim and age of claimant. All cost variables were log transformed to correct for non-

normality and unequal variances. The total cost of a claim changed by 1.76% for a one year increase in the age of claimant,  $\beta = .0176$ ,  $t(1) = 24.3$ ,  $p < .0001$ . The medical cost of a claim changed by 1.11% for a one year increase in the age of the claimant,  $\beta = .0111$ ,  $t(1) = 16.15$ ,  $p < .0001$ . The indemnity cost of a claim changed by 3.51% for a one year increase in the age of a claimant,  $\beta = .0351$ ,  $t(1) = 34.42$ ,  $p < .0001$ .

### **Description of causes of injuries by age groups**

Over half of all causes of injuries were attributed: strain, striking against or stepping on and falls, slips and trips (see Table 4). Falls, slips and trips were most common among workers ages 65 years and older where this type of cause accounted for 29% of all injury causes. Falls from a different level occurred most frequently among younger age groups and least frequent among older age groups. In contrast, falls on ice or snow or from the same level were most common among older age groups and least common among younger age groups (see Figure 6).

Strains were among the most common causes of injuries overall, but were ranked as the most frequent cause among the middle-aged groups (35-44, 45-54, 55-64). The distribution of types of strains did not vary greatly across all age groups except workers 65+ who experienced more strains from lifting and fewer strains from twisting compared to other age groups (see Figure 7). Cuts, punctures and scrapes occurred more frequently among younger age groups (see Table 4). Causes classified as “miscellaneous” were more common among younger age groups and the most common cause type under this category was foreign body in eye. All other types of causes of injuries did not vary greatly among the different age groups. Small point-biserial correlations between age when injured and each cause of injuries were found to be significant. For example a positive point-biserial correlation was found between age when injured and fall,



slip or trip ( $r_{pb}=.0699, p<.0001$ ) and strain ( $r_{pb}=.0642, p<.0001$ ) and a negative point-biserial correlation for cut, puncture or scrape ( $r_{pb}=-.0915, p<.0001$ ).

Table 4

*Distribution of cause of injury by age group*

|                                 | Age group |                   |      |                   |      |                   |      |                   |      |                  |      |              |
|---------------------------------|-----------|-------------------|------|-------------------|------|-------------------|------|-------------------|------|------------------|------|--------------|
|                                 | Rank      | 18-24<br>N=21,733 | Rank | 25-34<br>N=36,018 | Rank | 35-44<br>N=27,092 | Rank | 45-54<br>N=16,360 | Rank | 55-64<br>N=5,259 | Rank | 65+<br>N=603 |
| Strain                          | 2         | 4,570 (21%)       | 1    | 9555 (27%)        | 1    | 7810 (29%)        | 1    | 5039 (31%)        | 1    | 1550 (30%)       | 2    | 150 (25%)    |
| Striking against or stepping on | 1         | 5,026 (23%)       | 2    | 7273 (21%)        | 2    | 5088 (19%)        | 3    | 2996 (18%)        | 3    | 952 (18%)        | 3    | 118 (20%)    |
| Fall, slip, or trip             | 5         | 2769 (13%)        | 4    | 5197 (14%)        | 3    | 4494 (17%)        | 2    | 3014 (18%)        | 2    | 1128 (21%)       | 1    | 173 (29%)    |
| Cut, puncture, scrape           | 3         | 4236 (20%)        | 3    | 5793 (16%)        | 5    | 3531 (13%)        | 5    | 1695 (10%)        | 5    | 516 (10%)        | 5    | 55 (9%)      |
| Miscellaneous                   | 4         | 3037 (14%)        | 5    | 4918 (14%)        | 4    | 3589 (13%)        | 4    | 2019 (12%)        | 4    | 597 (11%)        | 4    | 59 (10%)     |
| Caught in, under or between     | 6         | 1107 (5%)         | 6    | 1610 (4%)         | 6    | 1096 (4%)         | 6    | 649 (4%)          | 6    | 201 (4%)         | 7    | 14 (2%)      |
| Motor vehicle                   | 8         | 383 (2%)          | 8    | 624 (2%)          | 9    | 383 (2%)          | 7    | 363 (2%)          | 7    | 120 (2%)         | 6    | 20 (3%)      |
| Burn or scald                   | 7         | 476(2%)           | 7    | 651 (2%)          | 7    | 473 (2%)          | 8    | 265 (2%)          | 9    | 80 (2%)          | 9    | 6 (1%)       |
| Repetitive motion               | 9         | 128 (.6%)         | 9    | 396 (1%)          | 8    | 435 (2%)          | 9    | 320 (2%)          | 8    | 115 (2%)         | 8    | 8 (1%)       |

Note. Miscellaneous includes cumulative (all other), foreign body in eye, misc (other than physical injury), other, robbery or criminal assault

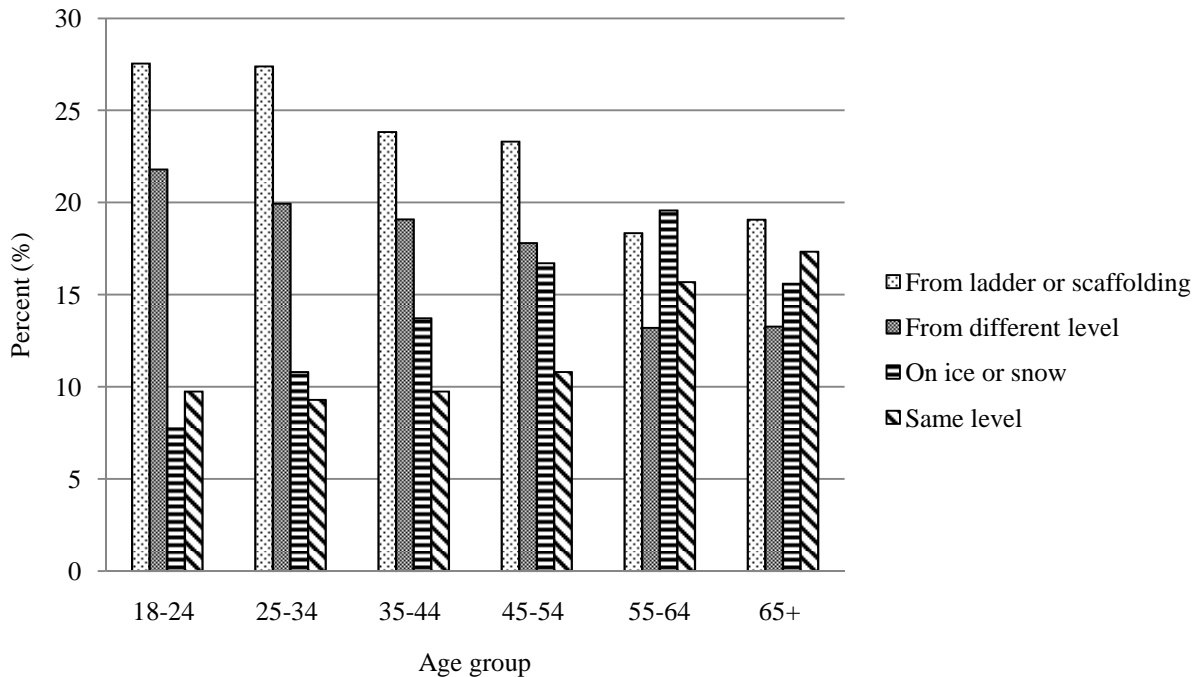


Figure 6. Distribution of the most frequent fall, slip or trip causes of injuries by age

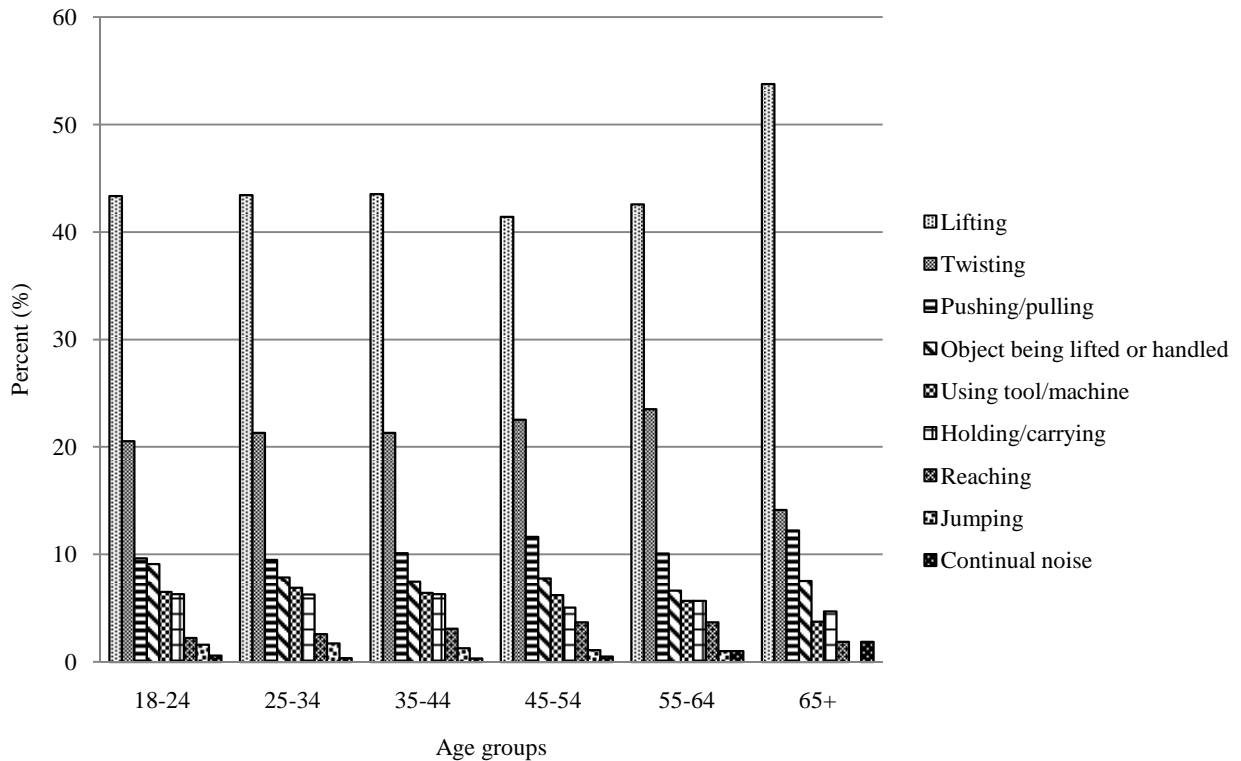


Figure 7. Distribution of the most frequent strain causes of injuries by age group

### The relationship between causes of injury and cost by age group

The most frequent causes of injuries were not necessarily the most costly. For example, motor vehicle accidents were the most costly, especially among older age groups (see Figure 8). When the motor vehicle category was broken down into the different types of accidents (e.g., with another vehicle, a rail vehicle, water vehicle, airplane or miscellaneous) a motor vehicle crash with another vehicle was the most common (56% of all motor vehicle causes). Repetitive motion injuries occurred least frequently overall, but were among the most costly for older age groups (65+).

For the most frequent causes of injuries, the older age groups incurred more costs than the younger age groups. For example, the mean total cost of a strain was \$12,787 ( $SD$ =\$24,259)

among those 65 and older, but only \$4,995 ( $SD=\$15,925$ ) among those between 18 and 24 years. Among the types of strains, objects being handled or lifted were most costly for workers ages 65 years and older, where as holding/carrying were most costly for workers ages 55-64, but there was little variation in cost by types of strains among workers 18 to 24 years of age (see Figure 11). A striking against or stepping on cause of injury cost more among older age groups, especially for workers 55-64 and 65 years and older (see Figure 8).

Falls, slips and trips were the second most costly type of cause overall. Mean costs were higher for the oldest four age groups, compared to the two youngest age groups. Costs related to falls from a different level were the most different by age group, with increasing cost by increasing age group (see Figure 12).

Older workers incurred greater costs associated with indemnity costs than younger workers. Medical costs were generally greater among older workers but costs dropped slightly for workers 65 years and older (see Figure 9). For example, some the most expensive medical costs corresponded to the oldest workers (65+) among motor vehicle, repetitive motion and miscellaneous causes of injury. Medical costs decreased among the oldest age group, however, for all other types of causes of injury. Older workers also generally incurred greater indemnity costs than younger workers (see Figure 10). For example, older workers (65+) who experienced a strain cause of injury incurred a mean of \$7,390 ( $SD=\$16,713$ ) indemnity costs whereas workers 18-24 incurred a mean of \$2,487 ( $SD=\$10,256$ ) indemnity costs. Older workers (65+) also incurred more indemnity costs than younger workers (18-24) for repetitive motion causes of injuries where mean indemnity costs were \$8,974 ( $SD=\$14,111$ ) and \$1,874 ( $SD=\$6,595$ ), respectively.

The following are results from the linear regression analyses for interaction effects between the cause of injury and age on the cost of claims (Table 5). “Step 1” of the linear regression analyses revealed that the relationship between cause of injury and cost of a claim was modified by age of the claimant. The Type III SS for the cause by age interaction term was 414.94 [ $F(8,107043) = 7.8, p < 0.0001$ ], 275.94, [ $F(8,107043) = 5.61, p < 0.0001$ ] and 1684.98, [ $F(8,107043) = 16.5, p < 0.0001$ ] for total cost, medical cost and indemnity cost, respectively. Thus, failing to reject the null hypothesis that the types of causes of injuries by age have equal slopes for all types of costs.

In the total cost model, the interactions with age were strongest for motor vehicle, repetitive motion and strain (Table 5). For example, there was an increase of 2.6%, 2.4% and 1.9% in the cost of injuries due to repetitive motion, motor vehicle and strain, respectively, per year increase in age. Also consistent with the descriptive analyses, there was no modification by age on the association between causes due to burn or scald or cut, puncture or scrape and total cost.

In the medical cost model, the interactions with age were strongest for motor vehicle and strain. There was an increase of 1.8% and 1.2% in the medical cost of injuries due to motor vehicle and strain, respectively, per year increase in age. Burn, caught in, under or between, cut, puncture or scrape, repetitive motion and miscellaneous all had a non-significant interaction with age in the final model.

The strongest interactions between the causes of injuries and age were found in the indemnity cost model. In the final model, only burn and cut, puncture or scrape had a non-significant interaction with age. The interactions with age were strongest for repetitive motion, motor vehicle, and strain. There was an increase of 6.8%, 4.3% and 3.8% in the indemnity cost

of injuries due to repetitive motion, motor vehicle and strain, respectively, per year increase in age.

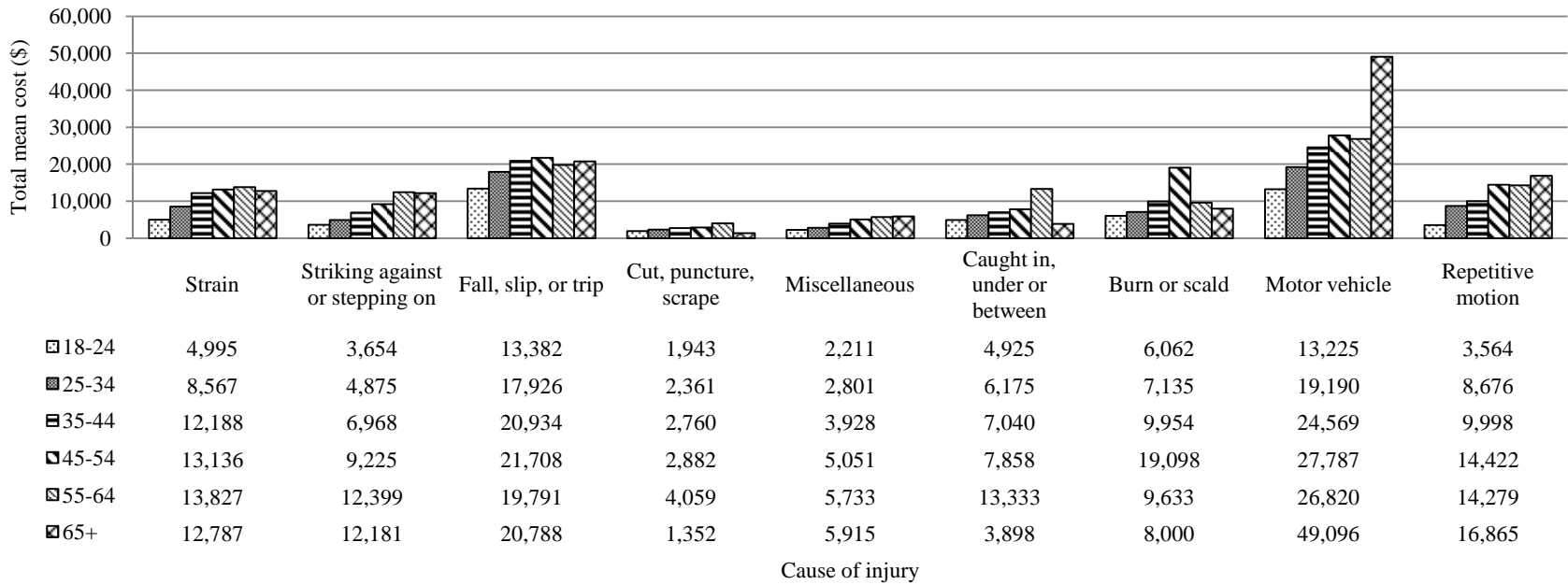


Figure 8. Total mean costs (\$) of cause of injury by age group

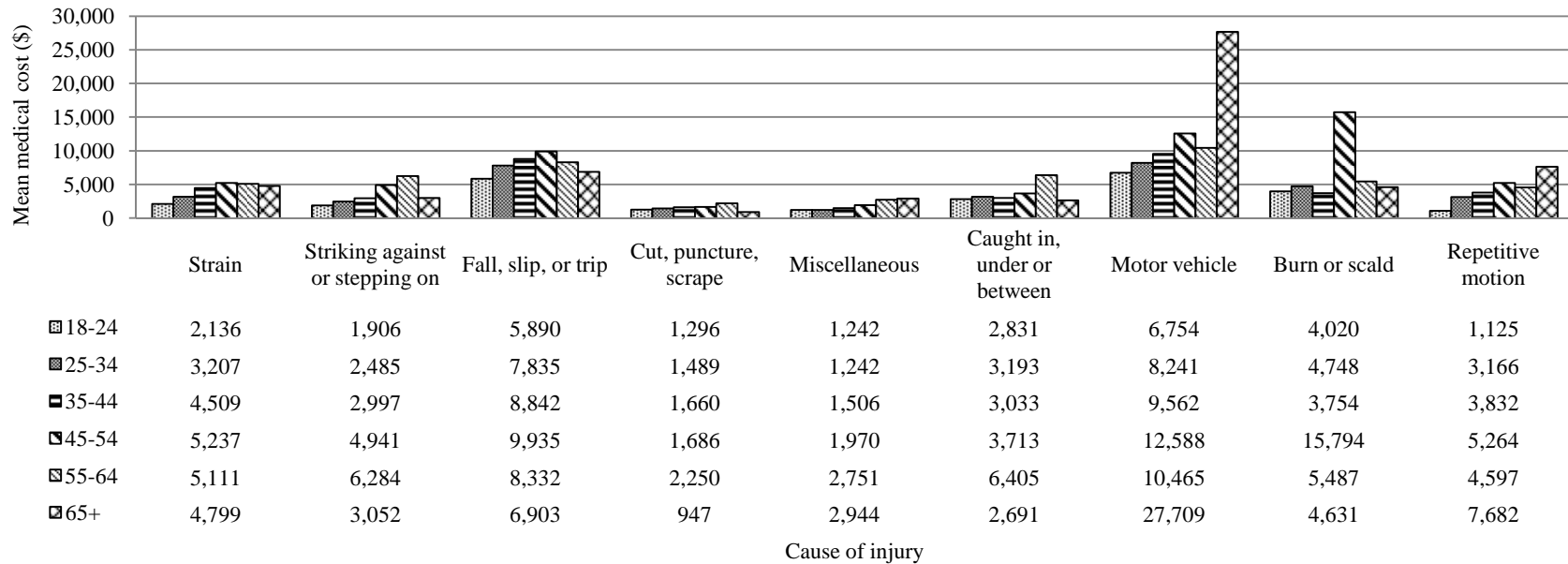


Figure 9. Mean medical costs (\$) of cause of injury by age group

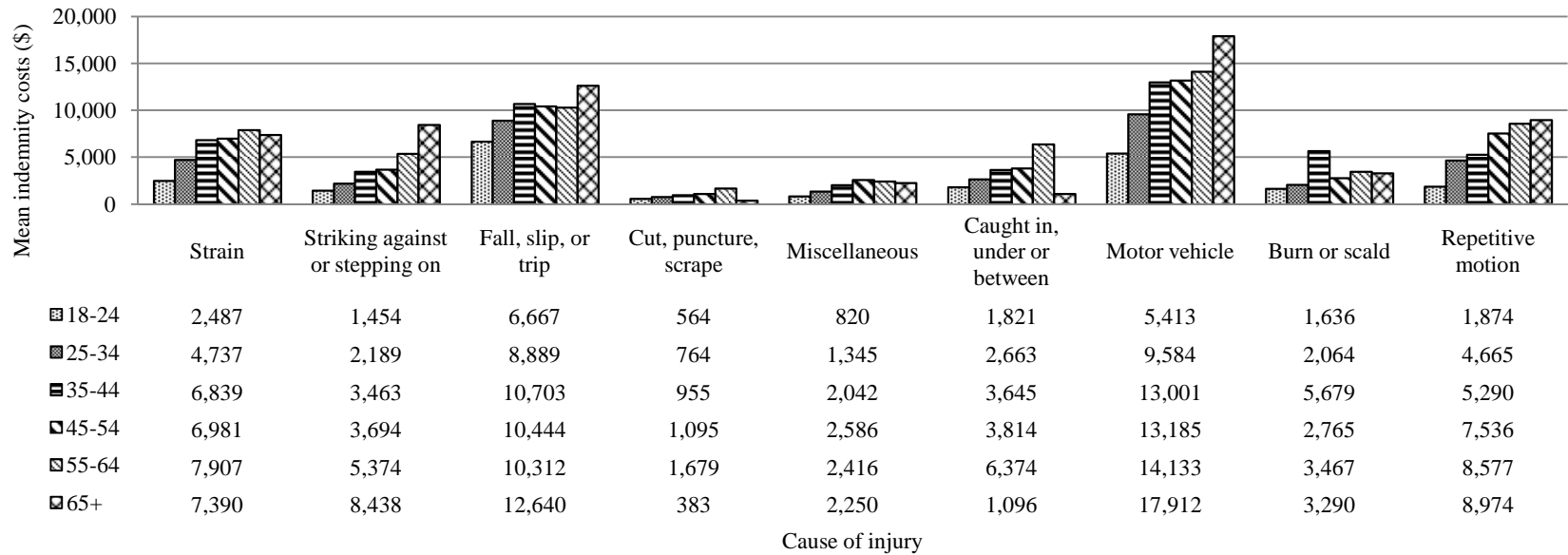


Figure 10. Mean indemnity costs (\$) of cause of injury by age group

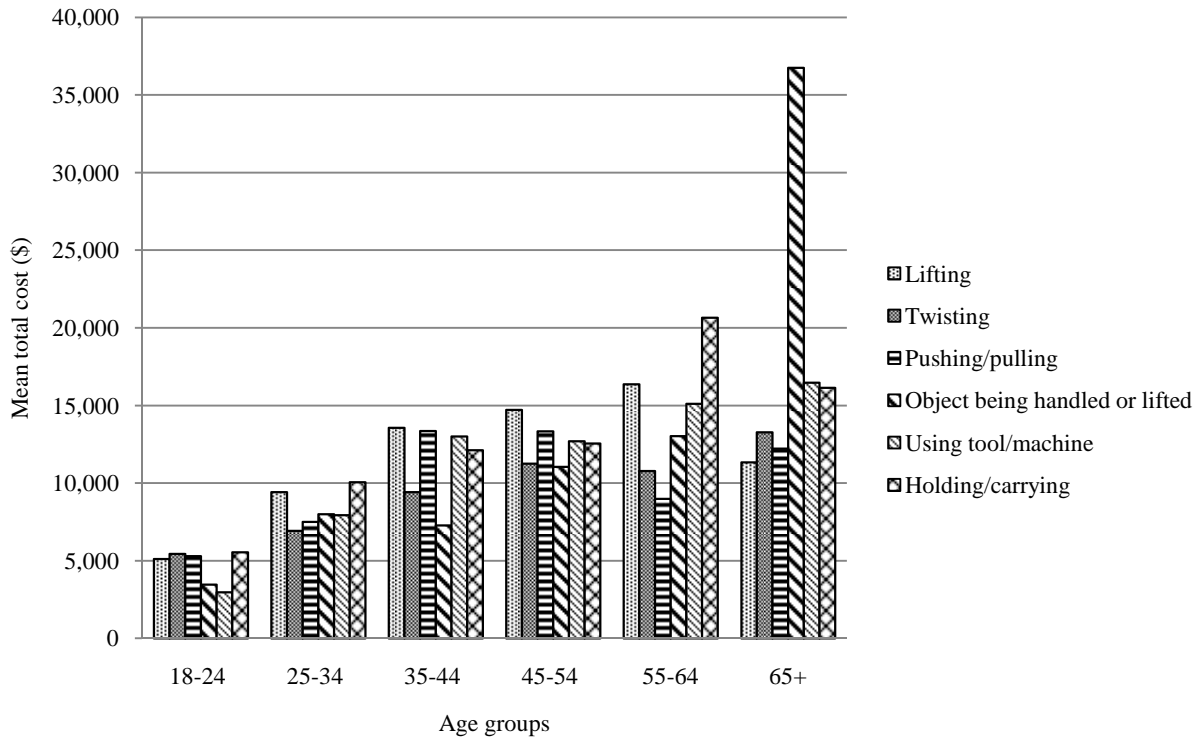


Figure 11. Mean total cost (\$) of the most frequent strain causes of injuries by age group

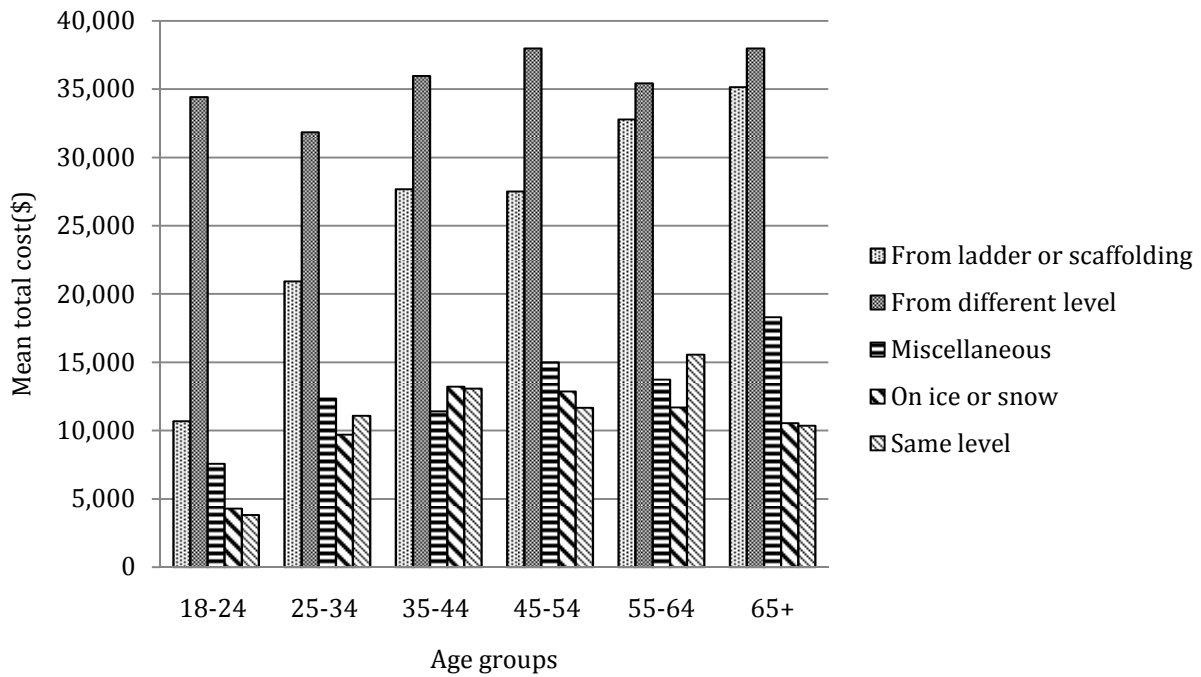


Figure 12. Mean total cost (\$) of the most frequent fall, slip or trip causes of injuries by age group



Table 5

*Results from linear regression models for the cost of a claim in relation to cause of injury and age of claimant*

|   | Total cost <sup>†</sup>         | Medical only cost <sup>†</sup>  | Indemnity only cost <sup>†</sup> |
|---|---------------------------------|---------------------------------|----------------------------------|
|   | Beta estimate (SE) <sup>a</sup> | Beta estimate (SE) <sup>a</sup> | Beta estimate (SE) <sup>a</sup>  |
|   | p-value                         | p-value                         | p-value                          |
| Burn or scald-heat or cold exposure-contact with*age <sup>b</sup> | -                               | -                               | -                                |
| Caught in, under or between*age <sup>b</sup>                      | -                               | -                               | .02 (.004)<br><i>p</i> <.0001    |
| Cut, puncture or scrape*age <sup>b</sup>                          | -                               | -                               | -                                |
| Fall, slip or trip*age <sup>b</sup>                               | .013 (.001)<br><i>p</i> <.0001  | .011 (.001)<br><i>p</i> <.0001  | .025 (.002)<br><i>p</i> <.0001   |
| Motor vehicle*age <sup>b</sup>                                    | .024 (.004)<br><i>p</i> <.0001  | .018 (.004)<br><i>p</i> <.0001  | .043 (.006)<br><i>p</i> <.0001   |
| Strain*age <sup>b</sup>   | .019 (.001)<br><i>p</i> <.0001  | .012 (.001)<br><i>p</i> <.0001  | .038 (.001)<br><i>p</i> <.0001   |
| Striking against or stepping on*age <sup>b</sup>                  | .013 (.001)<br><i>p</i> <.0001  | .008 (.001)<br><i>p</i> <.0001  | .025 (.002)<br><i>p</i> <.0001   |
| Repetitive motion*age <sup>b</sup>                                | .025 (.006)<br><i>p</i> <.0001  | -                               | .068 (.002)<br><i>p</i> <.0001   |
| Miscellaneous*age <sup>b</sup>                                    | .009 (.001)<br><i>p</i> <.0001  | -                               | .023 (.000)<br><i>p</i> <.0001   |

<sup>†</sup>Cost variables log-transformed

<sup>a</sup>Parameter estimates for each category of cause of injury modeled together. SE= standard error.

<sup>b</sup>Slope estimate for type of cause of injury and cost by age when injured (years)

- Not significant in the final model

### **Description of type of injury by age groups**

The relationship between the types of injury and age is described in Table 6. Over half of the injury types were comprised of strains, contusions and lacerations. Strains occurred more frequently among middle age groups (35-44, 45-54, and 55-64). Among the oldest age group, strains and contusions accounted for the majority of injury types, 26% and 27% respectively. Lacerations, foreign body and punctures were most frequent among younger age groups. Small point-biserial correlations between type of injury and age when injured were found to be significant. For example, positive point-biserial correlations were found between age when injured and sprain ( $r_{pb}=.0324, p<.0001$ ) and strain ( $r_{pb}=.0743, p<.0001$ ) and negative point-biserial correlations were found for laceration ( $r_{pb}=-.0799, p<.0001$ ) and puncture ( $r_{pb}=-.0695, p<.0001$ ).

Table 6

*Distribution of type of injury by age group*

|              | Age group |                   |      |                   |      |                   |      |                   |      |                  |      |              |
|--------------|-----------|-------------------|------|-------------------|------|-------------------|------|-------------------|------|------------------|------|--------------|
|              | Rank      | 18-24<br>n=21,733 | Rank | 25-34<br>n=36,018 | Rank | 35-44<br>n=27,092 | Rank | 45-54<br>n=16,360 | Rank | 55-64<br>n=5,259 | Rank | 65+<br>n=603 |
| Strain       | 3         | 4,437 (20%)       | 1    | 9,501 (26%)       | 1    | 8,115 (30%)       | 1    | 5,052 (31%)       | 1    | 1,594 (30%)      | 2    | 156 (26%)    |
| Contusion    | 1         | 4,608 (21%)       | 2    | 7,231 (20%)       | 2    | 5,646 (21%)       | 2    | 3,542 (22%)       | 2    | 1,215 (23%)      | 1    | 164 (27%)    |
| Laceration   | 2         | 4,455 (21%)       | 3    | 6,331 (18%)       | 3    | 3,987 (14%)       | 3    | 1,977 (12%)       | 3    | 628 (12%)        | 3    | 70 (12%)     |
| Foreign body | 4         | 1,851 (8%)        | 4    | 2,932 (8%)        | 4    | 1,961 (7%)        | 5    | 1,041 (6%)        | 6    | 287 (5%)         | 8    | 25 (4%)      |
| Sprain       | 6         | 1,206 (6%)        | 6    | 2,280 (6%)        | 5    | 1,931 (7%)        | 4    | 1,293 (8%)        | 4    | 409 (8%)         | 4    | 43 (7%)      |
| Puncture     | 5         | 1,964 (9%)        | 5    | 2,517 (7%)        | 6    | 1,389 (5%)        | 8    | 694 (4%)          | 9    | 200 (4%)         | 9    | 23 (4%)      |
| Other        | 7         | 933 (4%)          | 7    | 1,569 (4%)        | 7    | 1,313 (5%)        | 6    | 923 (6%)          | 5    | 322 (6%)         | 5    | 43 (7%)      |
| All other    | 9         | 745 (3%)          | 8    | 1,300 (4%)        | 8    | 1,046 (4%)        | 7    | 701 (4%)          | 8    | 224 (4%)         | 7    | 28 (5%)      |
| Fracture     | 8         | 763 (4%)          | 9    | 1,275 (4%)        | 9    | 932 (3%)          | 9    | 671 (4%)          | 7    | 236 (4%)         | 6    | 36 (6%)      |
| Crushing     | 10        | 389 (2%)          | 10   | 552 (2%)          | 10   | 387 (1%)          | 10   | 256 (2%)          | 10   | 80 (2%)          | 10   | 10 (2%)      |
| Burn         | 11        | 381 (2%)          | 11   | 526 (1%)          | 11   | 384 (1%)          | 11   | 210 (1%)          | 11   | 64 (1%)          | 11   | 5 (1%)       |

*Note.* “All other” was created by Pinnacol Assurance and includes everything that could not be categorized under their possibilities of type of injury. “Other” was created for this study and includes all type of injury possibilities that occurred less frequently (<1%).

## **The relationship between types of injury and cost by age group**

The most frequently occurring injury types were not the most costly. Fractures comprised between 4 and 6% of all types of injuries, but were the most costly type of injury across all age groups (see Figure 13). Types of injuries classified as “all other” were also among the most costly across all age groups. Since types of injuries classified as “all other” were originally coded as such, this type of injury could not be broken down by type further. Types of injuries classified as “other” were the third most costly. For the purposes of this study, the researcher created an “other” category in order to account for injury types that occurred the least frequently (<1%). The specific types of injuries that contributed to the cost of this “other” category were multiple injuries ( $M=\$57,909$ ,  $SD=\$132,908$ ), rupture ( $M=\$43,515$ ,  $SD=\$56,096$ ) and concussion ( $M=\$34,722$ ,  $SD=\$142,520$ ). The mean total cost increased by increasing age group for strains, contusions, sprains, all other, fractures and crushings. The remaining total costs by types of injury did not demonstrate clear trends by age groups.

Older workers tended to incur greater costs than younger workers. Older workers incurred a greater amount of medical costs than younger workers (see Figure 14). For example, workers 65 years and older incurred a mean of \$20,272 ( $SD=\$38,878$ ) medical costs whereas workers 18-24 years incurred a mean of \$11,649 ( $SD=\$30,732$ ) medical costs for fracture injuries. Older workers also incurred more indemnity costs than younger workers (see Figure 15). For example, workers 65 years and older incurred a mean of \$10,201 ( $SD=\$30,770$ ) indemnity costs where as workers 18-24 incurred a mean of \$2,116 ( $SD=\$22,150$ ) indemnity costs for a contusion injury.

The following are results from the linear regression analyses for interaction effects between the type of injury and age on the association with cost of claims (see Table 6). In “step

1” linear regression analyses revealed that the relationship between type of injury and cost of a claim was modified by age at the time of injury. The Type II SS for the type of injury by age interaction term was 651.66 [ $F(10,107039) = 9.94, p < 0.0001$ ], 366.87 [ $F(8,107038) = 6.03, p < 0.0001$ ] and 2614.14 [ $F(8,107038) = 20.97, p < 0.0001$ ] for total cost, medical cost and indemnity cost, respectively. Thus, failing to reject the null hypothesis that the types of injuries by age have equal slopes for all types of costs.

In the total cost mode, the interactions with age were strongest for a sprain (see Table 6), where there was an increase of 2.2% in the cost of a sprain injury per year increase in age. Burn, crushing, foreign body, laceration and puncture did not remain significant in the final model.

In the medical cost model, there was not a significant interaction between age and all other, burn, other, crushing, foreign body, fracture, laceration and puncture. Only sprains, contusions and strains remained significant in the final model where the medical cost of an injury was increased by 1.7%, 1.3% and 1.1%, respectively, per year increase in age.

The strongest interactions between the types of injuries and age were found in the indemnity cost model. The interaction between age and burns, foreign body, laceration and puncture did not remain significant in the final model. All other types of injuries had a significant interaction with age of the claimant. Sprain and strain types of injuries increased the indemnity costs of a claim by 3.5% for each year increase in age. Contusion and crushing types of injuries increased the indemnity costs of a claim by 3.4% for each year increase in age.

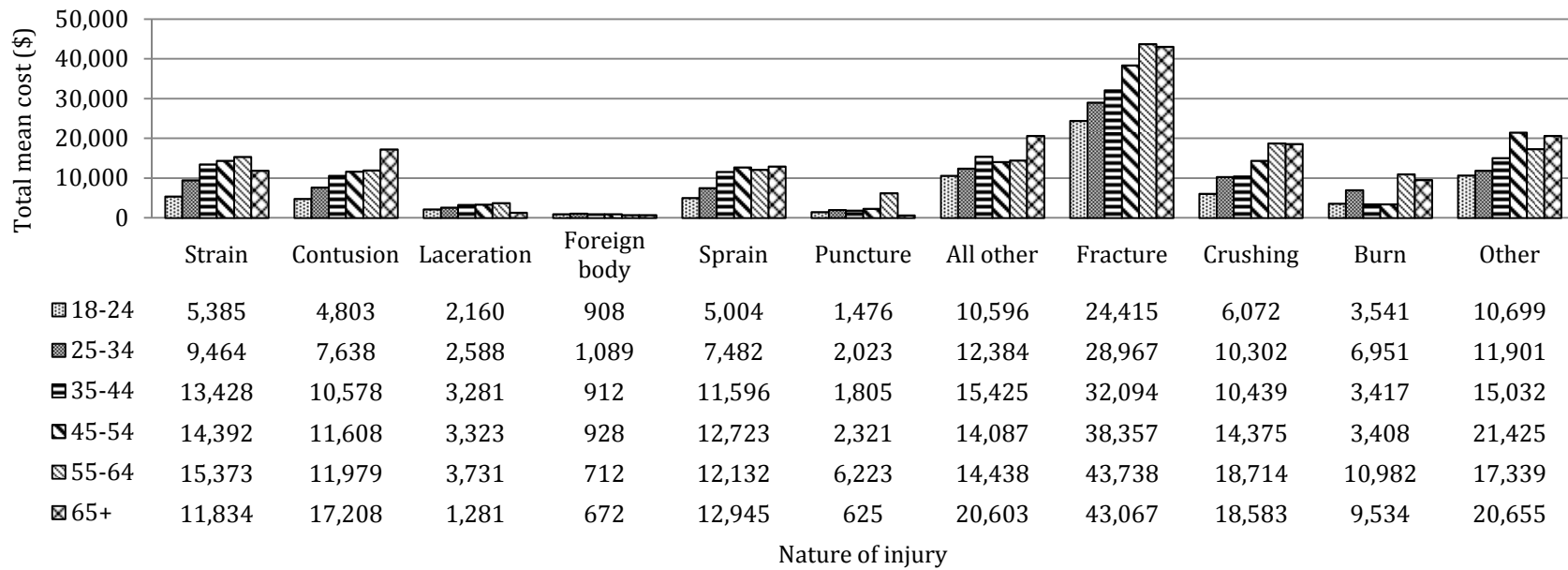


Figure 13. Total mean costs (\$) of type of injury by age group

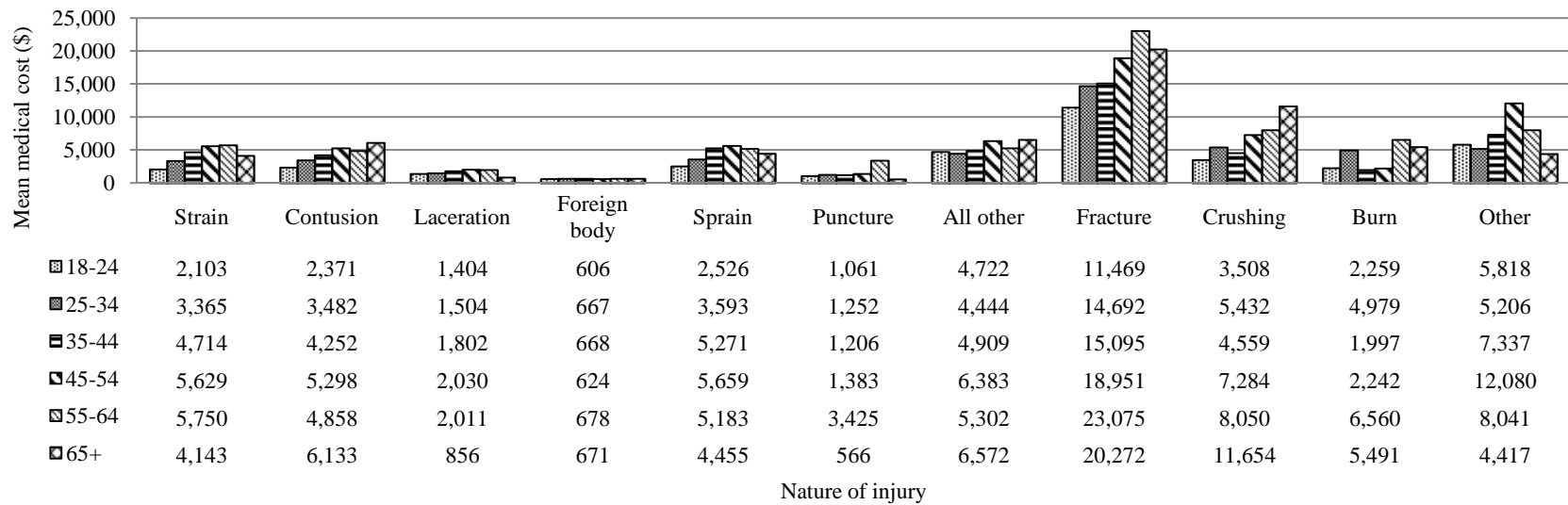


Figure 14. Mean medical costs (\$) of type of injury by age group

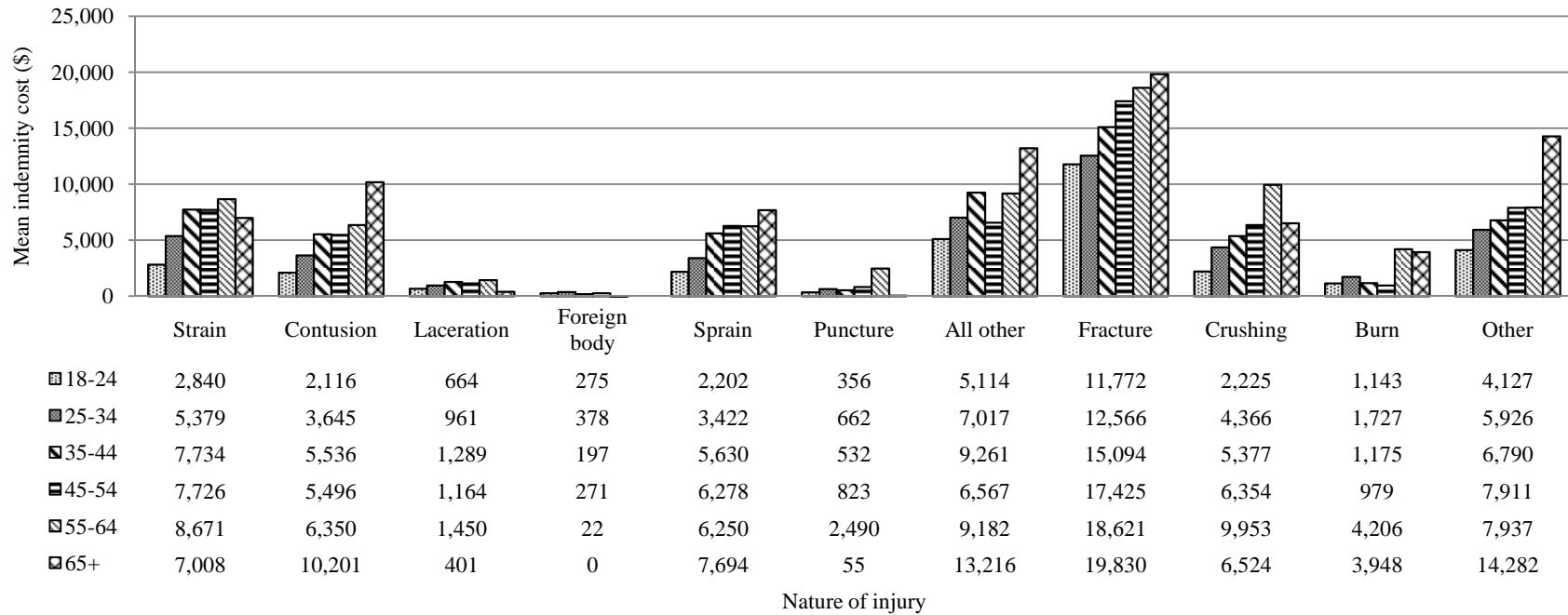


Figure 15. Mean indemnity costs (\$) of type of injury by age group

Table 7

Results from linear regression models for cost of a claim in relation to type of injury and age of claimant

|                               | Total cost <sup>†</sup>                    | Medical only cost <sup>†</sup>             | Indemnity only cost <sup>†</sup>           |
|-------------------------------|--|--|--|
|                               | Beta estimate (SE) <sup>a</sup><br>p-value | Beta estimate (SE) <sup>a</sup><br>p-value | Beta estimate (SE) <sup>a</sup><br>p-value |
| All other*age <sup>b</sup>    | .014 (.003)<br><i>p</i> <.0001             | -  | .035 (.004)<br><i>p</i> <.0001             |
| Burn*age <sup>b</sup>         | -  | -  | -  |
| Other*age <sup>b</sup>        | .018 (.003)<br><i>p</i> <.0001             | -  | .027 (.004)<br><i>p</i> <.0001             |
| Contusion*age <sup>b</sup>    | .018 (.001)<br><i>p</i> <.0001             | .013 (.001)<br><i>p</i> <.0001             | .034 (.002)<br><i>p</i> <.0001             |
| Crushing*age <sup>b</sup>     | -  | -  | .034 (.007)<br><i>p</i> <.0001             |
| Foreign body*age <sup>b</sup> | -  | -  | -  |
| Fracture*age <sup>b</sup>     | .014 (.003)<br><i>p</i> <.0001             | -  | .031 (.001)<br><i>p</i> <.0001             |
| Laceration*age <sup>b</sup>   | -  | -  | -  |
| Puncture*age <sup>b</sup>     | -  | -  | -  |
| Sprain*age <sup>b</sup>       | .022 (.002)<br><i>p</i> <.0001             | .017 (.002)<br><i>p</i> <.0001             | .035 (.003)<br><i>p</i> <.0001             |
| Strain*age <sup>b</sup>       | .017 (.001)<br><i>p</i> <.0001             | .011 (.001)<br><i>p</i> <.0001             | .035 (.001)<br><i>p</i> <.0001             |

<sup>†</sup>Cost variables log-transformed

<sup>a</sup>Parameter estimates for each category of type of injury modeled together. SE= standard error.

<sup>b</sup>Slope estimate for type of injury and cost by age when injured (years)

- Not significant in the final model

## Discussion

The results of this study support and build upon previous literature regarding costs, causes, and types of injuries in relative to age for the construction industry. Older workers generally incurred more workers' compensation costs but differences between age groups in terms of indemnity costs were more pronounced than differences based on direct medical costs alone. As previous literature suggests, older workers experience more injuries from strains and falls and sustain strain and contusion types of injuries more frequently than their younger counterparts. The statistical analyses in this study indicated that the relationship between cost and some causes of injuries and types of injuries depended on the age of the claimant. This



analysis suggests that older workers and younger workers do in fact experience significant differences in injuries and costs. Contractors who take the needs of the aging workforce into consideration may be able to reduce their workers' compensation premiums.

### **Age differences in the cost of a claim**

The workers' compensation claims in the present study represent a significant amount of occupational injury costs for the construction industry in the state of Colorado. Over the ten-year period, the total cost of the construction claims was approximately \$1 billion. The injuries and illnesses sustained in the construction industry make it one of the most expensive industries (Center for Construction Research and Training, 2008). According to the National Compensation Survey in 2005, the construction industry spent \$1.38 per hour worked on workers' compensation. This represents 5% of all compensation spent on employees, which is more than double the amount spent across all industries (Leigh & Robbins). It was unclear, from previous research, whether or not the costs (total, direct medical and indemnity) of injuries among older construction workers were significantly greater than younger workers. The present study undertook a comprehensive look into the effects of claimant age on injury cost, cause, and type in order to fill this gap in literature.

The cost of occupational injury among older construction workers was found to be significantly greater than younger workers in the present study. The total mean cost of a claim was significantly more for workers 35 years and older, compared to workers 34 years and younger. Some studies, however, have reported that total costs decline slightly with older age. In a study of Illinois workers' compensation claims for the construction industry from 2000-2005, the total mean cost of compensation peaked for workers aged 55 to 64 but declined slightly for workers over the age of 65 (Friedman & Forst, 2009). Another study of construction injuries

nationwide requiring days away from work found that the total cost of injuries and illnesses peaked at ages 45-54 and declined for workers over the age of 55. Their cost estimates, however, came from the Survey of Occupational Injuries and Illnesses (2002 Annual Survey) collected by the Bureau of Labor Statistics and included a comprehensive estimate of societal costs that included direct, indirect and quality of life costs (Waehrer, et al., 2007). These studies only reported descriptive statistics so it is unclear whether or not there were statistical differences between their age groups. The present study indicated that there were no significant differences between the mean total cost of a claim among the four oldest age groups. Thus, the discrepancy in the cost of injuries among older workers between these studies and the present study may be minimal.

The mean medical cost of a claim was significantly more for workers over the age of 35, compared to workers less than 35 years. Making comparisons with previous research is difficult because increased workers' compensation medical costs among older construction workers have not been widely reported. Across all industries, The National Council on Compensation Insurance reported increased workers' compensation medical costs among older age groups (Shuford & Restrepo, 2005). In the construction industry, younger workers (20-24) have been found to be more likely to be treated and released from the emergency room after an injury, compared to workers over the age of 65, indicating greater medical costs among older workers due to a longer hospitalization stay (Schoenfisch, et al., 2010; Shishlov, Schoenfisch, Myers, & Lipscomb, 2011). These studies, however, utilized a dataset that included only occupational injuries that required an emergency room visit and may represent more severe injuries than the present study's dataset. Though the medical costs of a claim in the present study was significantly more for workers over the age of 35, the percent increase was minimal. The

medical cost of a claim only increased by 1% for each year increase in age, which indicates that medical costs were not driving the total cost of the claim for this particular study.

Though the present study indicated that the age of the claimant had minimal effects on medical costs, the workers' compensation data used in the present study may underestimate medical costs among injured older construction workers. In a study that utilized the Medical Expenditure Panel Survey between 1996 and 2002, it was found that less than half of total medical expenses for construction work-related injuries were paid by workers' compensation insurance (Dong, Ringen, Men, & Fujimoto, 2007). Lipscomb, Dement, Silverstein, Cameron and Glazner (2009) was able to demonstrate this by contrasting private insurance payment rates and workers' compensation claims for work-related back injuries among union carpenters. They reported that as the number of workers' compensation claims increased and as the length of time since injury increased so did the private insurance payment rate. Unfortunately, they did not report on this trend by age. They did indicate that private insurance payment rates were higher for those over 30 years old, compared to those less than 30 years old. Their study suggests a shift in cost of occupational injuries as workers' compensation claims close and care continues through private insurance. Shifts in medical care for older construction workers may be prevalent as one study has found that construction roofers who left the trade due to health reasons were older and had more medical and musculoskeletal conditions (Welch, et al., 2010). Thus, the present study may underestimate the true medical costs of occupational injuries among older workers.

Occupational injury costs among older construction workers were greatest for claims involving indemnity costs. While mean medical costs were greatest among construction workers older than 35, mean indemnity costs were greatest among workers over the age of 55.

Interestingly, 33% of workers over the age of 65 incurred indemnity costs but only 18% of workers between 18 and 24 incurred indemnity costs. Though previous research has reported increased medical and indemnity costs among older construction workers, they have not examined the cost differences by age. The present study was able to determine that even though medical costs do increase with age, indemnity costs were the major driver of the increased workers' compensation costs among older construction workers. Thus, the greatest difference between the cost of older and younger construction workers injuries is not treatment costs but rather how long recovery takes, the degree of disability that ensues and death benefits.

This is not surprising because previous research has reported more time off work among older construction workers. A study utilizing the injuries and illnesses reported to the Owner Controlled Insurance Program by all contractors hired for the construction of the Denver International Airport from 1990 to 1994, found that the rate of lost work time among construction workers over the age of 60 (3.8 per 100 workers) was greater than the rate among workers aged 20-29 (2.5 per 100 workers) (Lowery, et al., 1998). Previous research has also reported delayed return to work among older construction workers. Kucera et al. (2009), for example, found that the odds of having a claim with delayed return to work (>90 days after the claim was filed) was 1.6 among workers over the age of 45, compared to workers less than 30 years of age.

Previous research has also reported that older workers are more susceptible to severe injuries that result in disability. Disability among older construction workers has become a concern because of the difficulty to maintain health and productivity while performing construction work. The disabilities that result from injuries can affect worker's decisions to continue work in the construction industry. Previous research has shown that the decision to

retire due to missed work, functional impairment and disability is more common among older construction workers (Welch, et al., 2010). Job accommodation can enable continued work but in physically demanding industries like construction, accommodations may be difficult to obtain. Older construction workers may be placed in a difficult situation by having to weigh the benefits of continued work to retirement. The result may be a feeling of job lock due to financial benefits of continued work (Benjamin, et al., 2008) and presenteeism as a result of continued work in spite of illness.

### **Cause of injury cost by age**

The frequency distribution of the causes of injuries in the present study is consistent with previous findings. Strains, striking against or stepping on and falls, slips and trips accounted for more than half of all causes of injuries in the present study. Studies that have utilized the NEISS-Work and the BLS SOII databases also reported that these three types of causes of injuries are the most frequently occurring among non-fatal injuries (Center for Construction Research and Training, 2008; Schoenfisch, et al., 2010). The most common causes of fatal injuries in CPWR's report were falls, transportation and contact with objects (Center for Construction Research and Training, 2008). Motor vehicle accidents were not ranked among the most frequent causes of injuries in the present study. They were, however, the most costly cause of injury across all types of causes and most costly for the oldest age group. Since the present study did not describe the claims by fatality status, it is hard to say whether the indemnity costs are due to death benefits, days away from work or disability.

The relationship between the types of causes of injuries and cost (total, medical and indemnity) was moderated by the age of the claimant. The linear regression analyses revealed that the medical expenses of the claim were not driven by the age of the claimant as much as the

indemnity expenses of the claim were for each cause of injury. In some cases, the age of the claimant did not moderate the relationship between the medical cost of a claim and the type of cause of injury. Older workers most frequent injury causes, strains and falls, slips and trips, resulted in a greater amount of medical and indemnity costs than younger workers with the same injury. Older workers also incurred a greater amount of costs for causes of injuries that were infrequent, such as motor vehicle accident and repetitive motion. It seems that, regardless of the cause of injury, older workers generally incur more workers' compensation costs than younger workers.

Injuries caused by falls are a major concern for the construction industry as they have been frequently ranked among the most common causes (e.g., Center for Construction Research and Training, 2008; Dement & Lipscomb, 1999). The present study determined that falls, slips and trips were the leading causes of injury and resulted in more indemnity than medical costs among older workers (65+). Consistent with previous research (e.g., H. Lipscomb, et al., 2003), results from the present study indicated that older workers were more likely to become injured by falling from the same level rather than from elevation yet regardless of the type of fall, older workers incurred more costs than younger workers. Studies involving occupationally related falls treated in the hospital emergency room found that older workers were more likely to be hospitalized from same level falls, indicating a greater severity of injury among older workers (Layne & Pollack, 2004; Schoenfisch, et al., 2010; Shishlov, et al., 2011). Fractures are frequently the result of falls and older age has been associated with increased cost of fracture injuries regardless of the type of fall (Courtney, Sorock, Manning, Collins, & Holbein-Jenny, 2001; H. Lipscomb, et al., 2003; Smith, et al., 2006). The present study found that fracture injuries were not the most commonly occurring types of injury but they were the most costly for

older workers. Though this study did not examine relationships between causes and types of injuries, these trends indicate that older worker's injuries due to falls, slips and trips are more serious and result in greater costs associated with wage-replacement and disability costs.

Motor vehicle causes of injuries occurred infrequently among all age groups but resulted in the greatest costs among older age groups. Previous research has found that motor vehicle accidents occur infrequently (Glazner, Bondy, Lezotte, Lipscomb, & Guarini, 2005) but result in the most severe injuries (Glazner, et al., 2005; Schoenfisch, et al., 2010). They are the second leading cause of occupationally related deaths in the construction industry (Center for Construction Research and Training, 2008) and older workers are more likely to die from an accident than younger workers (NIOSH, 2005; Rogers & Wiatrowski, 2005). The present study indicated that workers 65 years and older had a mean total cost almost triple the cost of the youngest age group related to motor vehicle accidents. Even though the present study could not account for fatality trends, it is clear that older workers experience the most severe injuries due to motor vehicle accidents. Changes in vision, reaction times, cognitive function, decreased muscle strength and range of motion can contribute to motor vehicle injuries among older workers. Other factors such as seat belt use, distractions, and fatigue may also affect workers ability to drive (NIOSH, 2005). The specific factors that contribute to construction related motor vehicle injuries should be addressed in order to prevent the most severe injuries older construction workers experience.

### **Type of injury cost by age**

The present study examined the most frequent injuries among different age groups and thus could not provide specific injury details. As stated previously, the present study did not examine the relationship between injury cause and type as previous research has. For example,

the types of injuries associated with falls among older workers in the construction industry are not only strains, contusions and lacerations but fractures as well (e.g., Layne & Pollack, 2004; H. Lipscomb, et al., 2003; Shishlov, et al., 2011; Smith, et al., 2006). The present study also did not examine the body parts associated with the injury type. Previous studies that were interested in musculoskeletal disorders have examined the prevalence of various body parts affected by injury (e.g., Engholm & Holmstrom, 2005). Though the present study did not take a detailed look into the injury event, it did show that older construction workers sustain different types of injuries than younger construction workers and that the indemnity cost of older construction workers most frequent injuries was greater than younger workers who experienced the same injury.

The relationship between the most frequent types of injuries sustained by older workers and cost was moderated by the age of the claimant. In the linear regression analyses, all types of injuries that remained significant in the final indemnity cost only model exhibited similar percent increases in the indemnity cost of a claim for each year increase in age. In the medical cost only model, the moderation by age was either minimal or nonexistent. These results confirm the findings of a recent review of literature regarding the aging workforce in the construction industry by showing that the costs associated with lost work days, disability and death are the greatest among older workers (Choi, 2009). Older workers most frequent injuries, strains and contusions, had a significant relationship in the indemnity cost only model that was moderated by age. Older workers least frequent injuries (lacerations, punctures, foreign body and burn), however, did not have a significant relationship with the cost (total, medical and indemnity) of a claim that was moderated by age. The present study shows that the most frequent injuries among older construction workers are the most costly for older workers.



This study supports previous research that indicates injuries to the musculoskeletal system are of particular concern for older construction workers (e.g., Center for Construction Research and Training, 2008; de Zwart, Frings-Dresen, & van Duivenbooden, 1999; Hoonakker & van Duivenbooden, 2010; Welch, et al., 2008; Welch, et al., 2010). Older workers experienced a greater proportion of injuries by sprains and strains and experienced strain type of injuries than younger workers. Repetitive motion injuries were not frequent but resulted in the largest increase in indemnity costs among older workers, a 6.8% increase in the cost of an indemnity cost of a claim per year increase in age. Age was found to be “the single most important factor associated with musculoskeletal disorders” by a cross-sectional study of over 85,000 Swedish construction workers that utilized the general standardized Nordic questionnaire for assessing musculoskeletal symptoms (Engholm & Holmstrom, 2005). In another study that utilized a similar questionnaire, Merlino et al. (2003) found that symptoms of musculoskeletal pain were common among apprentice construction workers, indicating that the physical nature of construction work impacts workers at even a young age. A strong dose-response relationship between physical work factors involving awkward postures (i.e. stooping/twisted postures, hands above the shoulder, and kneeling postures) (Engholm & Holmstrom, 2005) and working in the same position (Merlino, et al., 2003) and musculoskeletal disorders has been found in the construction industry. Thus, the physical nature of construction work that construction workers are exposed to throughout employment can result in a significant amount of injuries that force older workers to take a greater amount of time off work to recover and/or limit their ability to perform the same work after injury.

Since only the most frequent injuries in the database were included in the present study's analyses, the present study could not account for the costs of infrequent injuries and illnesses

among older construction workers. This means that the present study did not account for cost and age differences in terms of each illness (e.g., hearing loss or asbestosis) because they were infrequent. The present study also may miss serious illnesses due to the fact that the most serious work-related illnesses in construction take years to develop. Leigh and Robbins (2004) examined the ways in which workers' compensation misses the costs of serious occupational illness by comparing epidemiological data on occupational illnesses and workers' compensation data from seven states. They found that the majority of illnesses listed in the workers' compensation database were acute, non-life threatening and only comprised about 8% of all workers' compensation cases. Their study was able to show that in 1999, workers' compensation estimates of occupational illness missed \$8 billion to \$23 billion in medical costs. It is hard to say what percentage of the claims in the present study reflect illnesses since all of them fell into the "other" category, which included injuries as well, but the "other" category only represented approximately 4% of all types of injuries and illnesses. Therefore, based on studies of cost shifting of serious illnesses (e.g., Leigh & Robbins, 2004; H. J. Lipscomb, et al., 2009), it is reasonable to assume that the present study may have missed the most serious and costly injuries among older construction workers.

### **Recommendations**

Falls from the same level should be a major focus for the prevention of older construction workers injuries. There may be a number of reasons why older workers fall more frequently from the same level. Older workers may have had different work exposures, had more fall protection safety training or had more experience with the dangers of falls from heights. While these results show that preventing falls from heights is important, it is equally important to prevent falls from the same level. Occupational Safety and Health Administration regulates falls

from heights (e.g., scaffolds, roof, and ladders) but falls from the same level do not receive the same amount of attention (H. Lipscomb, et al., 2003). Contractors should ensure that their walking surfaces are clean, free of obstacles, clear of ice and snow, and well lit. By targeting older workers most frequent types of falls, contractors will be able to avoid increased workers compensation premiums associated with older workers frequent and severe injuries.

Work demands in the construction industry may be more difficult for older construction workers. Attention to work design and methods may be an important strategy to reduce some of their most frequent injuries. McMahan and Phillips (1999) recommend that employers and workers reduce extreme joint movement, excessive force and highly repetitive tasks in order to compensate for older workers decrease in physical capacities. Contractors should utilize methods to reduce the need for workers to lift extremely heavy objects since lifting 80 pounds is not an uncommon work task in the construction industry (Center for Construction Research and Training, 2008). Contractors should evaluate work tasks to determine appropriate lifting, pushing, pulling and carrying schedules by using the *Liberty Mutual Manual Materials Handling Tables* (Liberty Mutual Group, 2004). They can also use NIOSH's *Simple Solutions: Ergonomics for Construction Workers* booklet that explains why various work tasks cause injury, potential solutions for contractors and the approximate implementation cost (NIOSH, 2007). Modifying work tasks in the construction industry has been slow to catch on (Center for Construction Research and Training, 2008). Researchers should continue to evaluate tools and work tasks in the construction industry so that methods to reduce musculoskeletal disorders are easy and cost effective for contractors to implement.

### **Future research priorities**

Future research should utilize a combination of leading and lagging safety and health performance metrics to determine the relationship between safety, injury and age in the construction industry. Safety and health performance metrics can be used to monitor the level of safety or to motivate those in a position of power to take necessary actions to improve safety. These metrics can also be used to determine how to take action (Hale, 2009). Leading indicators of safety (i.e., actions, events and processes that precede the event from occurring) should be tracked by using such metrics as use of personal protective equipment, reporting unsafe conditions/actions, or participation in health and safety meetings. Lagging indicators (i.e., reactive measures of safety) can also be utilized by tracking existing occupational injury data (e.g., workers compensation claims, Bureau of Labor Statistics' Survey of Occupational Injuries and Illnesses, or National Electronic Injury Surveillance System-Work). By tracking a combination of leading and lagging indicators, the relationship between age, safety, and injury can be determined and the appropriate interventions can be developed.

Crawford, Graveling, Cowie & Dixon's (2010) review of the health and safety needs of older workers found that there were no intervention studies that specifically evaluated strategies to reduce injuries in older workers. The next steps in the analysis of older workers injuries should be to determine the specific factors surrounding injury events that result in frequent and costly injuries to older construction workers. This could be done by utilizing the following variables and methods: (1) "source of injury" (e.g., hand tools, ladders, saw, vehicles, etc.), which describes the cause of injury in further detail by indicating the origin of the injury, (2) "body part" to specify the location on the body where the injury occurred, (3) "construction trade," and lastly (4) estimate the specific work task exposures by trade using the Occupational Information Network (National Center for O\*NET Development, 2011), which provides specific

job analyses and descriptions. The result would be detailed descriptions of injury events that can target interventions. For example, the results from this study indicated that older workers are most susceptible to strain injuries by lifting: (1) the source of injury variable could reveal that workers were most frequently injured by lifting containers (2) the body part variable could indicate that the worker injured their lower back as a result of lifting containers (3) a cross tabulation of strain causes of injuries by lifting containers and construction trade could then reveal that carpenters experienced this injury combination most frequently (4) finally, O\*NET could be used to determine work tasks that carpenters engage in that contribute to this injury event. Interventions could then be developed to target the work tasks that could result in this injury event. The interventions should then be evaluated and disseminated to contractors and organizations involved with construction worker safety and health.

Since all occupational injuries cannot be mitigated, return to work and disability management for older workers should also be a priority for future research. This study shows that older workers incur more costs associated with serious injuries than younger workers. The American College of Occupational and Environmental Medicine (ACOEM) states that it is imperative that more attention and resources be devoted to protect the employability of the working-age population in order to mitigate the impending consequences of the health care crisis brought on by chronic disease among the baby boomers (Special committee on health, 2009). Managing injuries among older workers should provide a good balance between work performance, health and mental resources in order to prevent older workers from retiring early from construction work (Alavinia, de Boer, van Duivenbooden, Frings-Dresen, & Burdorf, 2009). Such management programs may not be fully implemented, however, if employers are unaware of the benefits of older workers and the methods to retain their employment. Employers

may be unaware of the evidentiary base for programs and policies regarding older workers.

Efforts towards disseminating results and recommendations to the construction industry should be a priority for researchers (Silverstein, 2008).

### **Limitations**

The use of workers' compensation data to describe occupational injuries and illnesses can be informative but there are significant limits to its use. The database of claims was created to manage insurance payments not for occupational health surveillance. Thus, the researchers could not control the questions asked or the reliability of the data entry on the first report of injury form. Workers' compensation data may underestimate the true frequency and cost of older workers injuries in Colorado because of potential underreporting and contractor's use of other workers' compensation insurers. Also, this study limited the claims to only those that were "closed" and thus missed the claims that are still open and incurring costs. Lastly, the present study was not able to calculate rates of injury because information on the injured workers who filed the claim could not be easily accessed.

### **Conclusion**

The impact of the aging population on the construction industry is significant. While this study indicated that older workers are injured less frequently, the workers compensation costs incurred by them are more costly on a per claim basis than their younger counterparts. The increase in costs, however, seemed to be most significant in terms of indemnity costs alone. The shift towards an older work force will result in an increase in the proportion of occupational injuries among older workers, which will result in increased costs associated with severe injuries and disabilities. Employers who wish to remain competitive must effectively manage a health and safety program that acknowledges the needs of the aging worker. Encouraging companies to

address the specific needs of older workers is the first step in reducing the frequency and cost of occupational injuries related to older age.

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## Appendix

Table 1

*Cause of injury coding scheme*

| Code | Cause of injury                               | Code grouped | Cause of injury grouped                              |
|------|---|--------------|--|
| 7    | animal or insect                              | 1            | burn or scald – heat or cold exposure – contact with |
| 1    | burn - dust, gas, fume, vapor                 | 2            | caught in, under or between                          |
| 1    | burn - miscellaneous                          | 3            | cut, puncture or scrape                              |
| 1    | burn-acid chemicals                           | 4            | fall, slip or trip                                   |
| 1    | burn-contact hot object                       | 5            | motor vehicle  |
| 1    | burn-fire, flame                              | 6            | strain   |
| 1    | burn-radiation                                | 7            | striking against or stepping on                      |
| 1    | burn-steam, hot fluids                        | 8            | repetitive motion                                    |
| 1    | burn-temp. extremes                           | 9            | miscellaneous  |
| 1    | burn-welding operations                       |              |  |
| 2    | caught-machinery                              |              |  |
| 2    | caught-object handled                         |              |  |
| 1    | cold objects or substances                    |              |  |
| 2    | collapsing materials (slides of earth)        |              |  |
| 5    | crash of rail vehicle                         |              |  |
| 5    | crash of water vehicle                        |              |  |
| 9    | cumulative (all other)                        |              |  |
| 3    | cut - miscellaneous                           |              |  |
| 3    | cut-broken glass                              |              |  |
| 3    | cut-tool powered                              |              |  |
| 3    | cut-tool, not powered                         |              |  |
| 1    | electric shock-contact w/electric current     |              |  |
| 1    | explosion or flare back                       |              |  |
| 4    | fall - miscellaneous                          |              |  |
| 4    | fall - same level                             |              |  |
| 4    | fall on ice or snow                           |              |  |
| 4    | fall or slip from different level             |              |  |
| 4    | fall or slip from ladder or scaffolding       |              |  |
| 4    | fall or slip from liquid or grease spills     |              |  |
| 4    | fall, into opening                            |              |  |
| 4    | fall, on stairs                               |              |  |
| 4    | fall-slip, no fall                            |              |  |
| 9    | foreign body in eye                           |              |  |
| 9    | misc, other than physical cause of injury     |              |  |
| 2    | miscellaneous caught in or between            |              |  |
| 5    | miscellaneous motor vehicle                   |              |  |
| 6    | miscellaneous strain or injury                |              |  |
| 7    | miscellaneous strike or injury                |              |  |
| 7    | miscellaneous striking against or stepping on |              |  |
| 5    | mot. Veh-coll/fixd object                     |              |  |
| 5    | motor veh-airplane crash                      |              |  |

- 5 motor veh-coll/vehicle
  - 5 motor vehicle-upset
  - 6 object being lifted or handled
  - 9 other
  - 8 repetitive motion
  - 9 robbery or criminal assault
  - 6 strain or injury by continual noise
  - 6 strain or injury by twisting
  - 6 strain-holding, carrying
  - 6 strain-jumping
  - 6 strain-lifting
  - 6 strain-pushing, pulling
  - 6 strain-reaching
  - 6 strain-using tool/machine
  - 7 strike-lifted object
  - 7 strike-moving parts
  - 7 strike-sanding, cleaning
  - 7 strike-stationary object
  - 7 strike-step, sharp object
  - 7 struck by-falling object
  - 7 struck by-lifted object
  - 7 struck by-motor vehicle
  - 7 struck by-moving parts
  - 7 struck by-object by other
  - 7 struck by-tool, machine
  - 7 struck or injured by fellow worker,  
patient
  - 6 strain or injury - miscellaneous
-



Table 2

*Type of injury coding scheme*

| Code | Nature                                    | Code grouped | Nature grouped |
|------|---|--------------|----------------|
| 1    | all other                                 | 48           | Strain         |
| 11   | cumulative injuries                       | 14           | Contusion      |
| 11   | occupational diseases                     | 30           | Laceration     |
| 11   | amputation                                | 21           | Foreign body   |
| 11   | angina pectoris                           | 47           | Sprain         |
| 11   | asbestos                                  | 40           | Puncture       |
| 11   | asphyxiation                              | 1            | All other      |
| 11   | black lung                                | 22           | Fracture       |
| 9    | burn                                      | 15           | Crushing       |
| 11   | cancer                                    | 9            | Burn           |
| 11   | carpal tunnel syndrome                    | 11           | Other          |
| 11   | contagious disease                        |              |                |
| 11   | contagious disease (incl. sar, pneumonia) |              |                |
| 14   | contusion                                 |              |                |
| 15   | crushing                                  |              |                |
| 11   | dermatitis                                |              |                |
| 11   | dislocation                               |              |                |
| 11   | dust disease noc                          |              |                |
| 11   | electric shock                            |              |                |
| 11   | enucleation                               |              |                |
| 11   | foreign body                              |              |                |
| 22   | fracture                                  |              |                |
| 11   | freezing                                  |              |                |
| 11   | hearing loss                              |              |                |
| 11   | heat prostration                          |              |                |
| 11   | hernia                                    |              |                |
| 11   | herniated disc                            |              |                |
| 11   | infection                                 |              |                |
| 11   | inflammation                              |              |                |
| 30   | laceration                                |              |                |
| 11   | mental stress                             |              |                |
| 11   | multiple physical injuries                |              |                |
| 11   | MYOCARDIAL INFARCTION                     |              |                |
| 11   | no physical injury                        |              |                |
| 11   | poisoning--general                        |              |                |
| 11   | poisoning--general(not od or cumulative)  |              |                |
| 11   | poisoning-chemical                        |              |                |
| 11   | poisoning-metal                           |              |                |
| 11   | posioning-chemical                        |              |                |
| 40   | puncture                                  |              |                |

11 radiation  
11 rapture  
11 respiratory disorders (incl. asthma)  
11 ruptured disc  
11 severance  
11 silicosis  
47 sprain  
48 strain  
11 unclassified  
11 vascular loss  
11 vision loss  
11 concussion  
11 mental stress  
11 rupture  
11 mental disorder  
11 multiple injuries both physical and  
11 aids  
11 VDT-RELATED DISEASE

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