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The Role of Age on the Cause, Type, Nature and Cost of Construction Injuries

CPWR Small Grant Final Report November 2012

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Abstract

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 100,000 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 natures of injuries and illnesses. Our findings indicate that while older construction workers filed a small percentage of the total workers' compensation claims, their injuries and illnesses were more costly compared to younger workers. The indemnity cost of a claim increased by 3.5% for each year increase in age whereas the medical cost increased by 1%. 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 nature of injury for workers over the age of 35 but workers over the age of 65 experienced strains and contusions at similar frequencies. This analysis suggests that aging construction workers and younger construction workers do in fact experience significant differences in injuries and costs.

Key Findings

- Older construction workers filed a small percentage of the total workers' compensation claims; however, when they did file a claim the associated costs were greater. This was especially true for the indemnity cost of a claim where the indemnity cost of a claim increased 3.5% for each year increase in age, where as the medical cost increased 1.1%.

- 29% of all claims filed by workers over the age of 65 were the result of a fall, slip or trip. A fall, slip or trip resulted in a 2.5% increase in the indemnity cost of a claim for each year increase in age. Falls to the same level or on ice or snow, specifically, were more common among older workers. Yet, the average cost of a fall to a different level was more costly, regardless of age.

- Strains, specifically from lifting, were the most common cause of injury among workers aged 35-64. A strain resulted in a 3.8% increase in the cost of a claim for each year increase in age.

- A repetitive motion cause of injury resulted in the greatest increase in cost with each year increase in age (6.8%) but was not cited frequently as cause of injury/illness among claimants.

- The most common nature of injury among workers over the age of 35 was strains but workers over the age of 65 experienced strains and contusions at similar frequencies. A strain and contusion injury resulted in a 3.5% and 3.4% increase in the indemnity cost of a claim for each year increase in age, respectively.

Introduction

The large birth cohort born between 1946 and 1964 combined with the collapse of financial markets and an economic recession during the first decade of the 21st century have led to a larger population of older workers in the US workplace. The twentieth century trend towards earlier retirement has reversed and growing numbers of employees are planning for longer working careers (NCCI, 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 5th, 6th, and even 7th, decade of life may be even more significant in terms of injuries for workers involved in traditionally high risk and physically demanding occupations such the construction industry. Employers who establish age friendly work environments that promote and support the workability of employees as they age may gain in safety, productivity, competitiveness, and sustainable business practices (Silverstein, 2008).

Given that aging has been associated with reduced physical capacities such as strength, balance, and processing speed, it is logical to predict that aging would be associated with less optimal performance and higher rates of injury (Maertens, et al., in press). Research on workers' compensation claims (NCCI, 2005; WCRI, 2002) however, indicates that older workers typically have lower rates of workplace injuries but their injuries are associated with higher costs. However, there is little research that has examined the nature and cause of those injuries for older workers, especially those in their late 50s and 60s (NCCI, 2005).

The goal of the proposed project is to determine the impact that the aging process has on workers in the construction industry as age relates to selected worker compensation variables. The investigators of this project have acquired a database of workers' compensation claims from Pinnacol Assurance (provides workers' compensation coverage for nearly 80% of Colorado construction companies). The database covers a 10-year period from 1998-2008 and consists of approximately 111,000 claims. The claims data will be analyzed to determine the influence of age on cost (direct medical and indemnity), nature, and cause of injury.

In addition to identifying factors that may place older works at greater risk for injury, the results generated from this project may provide the basis for future interventions aimed at developing workplaces and work methods that are less dangerous for older workers.

The proposed project goal is consistent with the 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. The proposed study specifically addresses sub-goal 12.2.4 by conducting research which addresses age related injury and illness characteristics. It also specifically addresses sub-goal 12.1.2 by and by exploring and implementing the use of other existing surveillance systems to address gaps in information about occupational injuries, illnesses and risk factors among at-risk workers in construction (NIOSH, 2009). Additionally, priority topics for future construction research were identified by the National Academies 2008 Program Improvement Recommendations and included a focus on subpopulations such as aging workers.

Specific Aims of Study

1. Determine the relationship between age and cost (direct medical and indemnity) associated with occupational related injuries and illnesses.

2. Determine and describe the relationship between age and causes of injuries and illnesses.

3. Determine the relationship between age and nature of injuries and illnesses.

Background

The number of workers in the workforce who are 55 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). There are many reasons for continuing to work including psychosocial and financial benefits. However, there are many barriers that prevent continued work.

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, et al., 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 (Sattlemair, 2009). Older adults are also susceptible to chronic inflammatory processes 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 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, especially in occupations that are already physically demanding.

By the nature of the trade, most construction workers experience a physically demanding work environment. The industry is characterized by long hours (Haslam, 2005), task variability, irregular work periods (Forde & Buchholz, 2004), unpredictable workplaces and noncontinuous 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 (Rosecrance, et al., 1996; Merlino, et al., 2003; LeMasters, 2006). Performing construction work, where multiple physical demands are present, can increase the probability of injury (Choi, 2009). Given the precarious and physically challenging work conditions coupled with aging trends, it is not hard to imagine the cost of injuries to older workers and the industry.

Haslam (2005) notes, "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, et al., 2007). Vulnerable populations, such as aging workers, comprise much of those costs. In general, workers compensation claim costs increase with the age of workers (Friedman & Forst, 2009). For example, Lipscomb (2003) found that costs associated with falls in construction were three times higher for those over 45 years as compared to those under 30 years of age. Lowery and associates (1998) determined that lost work time rates increased with age, which results in increased indemnity costs. Schoenfisch and colleagues (2010) determined that though older construction worker's injury rates were lower than younger workers, injuries were more likely to cause more serious conditions, greater chance of disability, require more hospitalization, and require more recovery time.

Despite the increased awareness and research related to construction health and safety over the last twenty years, the construction industry remains one of the most dangerous industries in the US. Injury trends among vulnerable workers, such as the growing number of aging workers, need to be studied within construction industry to assist in targeting specific interventions aimed at helping older workers stay employed and preventing age and workrelated injuries (Schoenfisch et al., 2010; Kisner & Fosbroke, 1994). Although the Bureau of Labor Statistics publishes the most comprehensive injury and illness data, it does not characterize the nature, source and cause of the injury by age for the construction industry (BLS, 2010). There

are no published studies specifically investigating aging trends among a large cohort of workers in the construction trade that report on the nature, cause, and costs of work-related injuries. The proposed study was the first comprehensive effort to identify aging related trends associated with compensation claim variables of injury nature, cause and costs.

Methods

Population studied

The dataset represented workers' compensation claims filed by construction workers in the state of Colorado between the June 30, 1998 and June 30, 2008. Because claims are "open" for some period of time following the initial injury, a 24-month claim period was chosen to use for the analysis of cost data. The 24-month period has been used in previous workers' compensation cost studies and represents a time frame with very little additional costs (<1%) after that period (personal communication with actuarial at Pinnacol, 2010). 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 represents working adults, therefore all claimants under the age of 18 were excluded.

Description of the dataset

A dataset was created in SAS from Colorado workers' compensation claims representing all construction trades as referenced by National Council on Compensation Insurance, INC. (NCCI) codes. Pinnacol Assurance removed all personal identifiers in the dataset and coded them with a unique claimant number before the dataset was given to the investigators at Colorado State University. Pinnacol Assurance kept separate file with the unique claimant number and claimant's name. All claims data were exported from Pinnacol's database into an excel spreadsheet and saved on a secure jump drive that was password protected and has the ability to remotely destroy its contents if tampered with. The Institutional Review Board (IRB) at Colorado State University has indicated by memo that the project was exempt from IRB since the data is not identifiable. A description of each variable used in the study is listed in Table 1 and the coding scheme for the cause and nature of injury variables can be seen in the Appendix. A distribution of age at time of claim can be seen in Figure 1.

Table 1. List of variables used in analyses for Specific Aims 1-3

Variable	Definition
Nature of injury	Injury sustained by claimant - From 1st report injury form
Cause of injury	Method of energy transfer that caused the injury - From 1st report injury form
Gross paid	Total amount paid per claim
Gross paid indemnity	Total indemnity costs per claim - Most often represents lost-time wages or disability payments
Gross paid medical	Total medical costs per claim
Claim type	Medical cost only claim or medical cost plus indemnity cost claim
Age	Age at time of injury
Gender	Male or female
NCCI code	Code assigned to the claim that represents the specific construction trade the claimant worked in

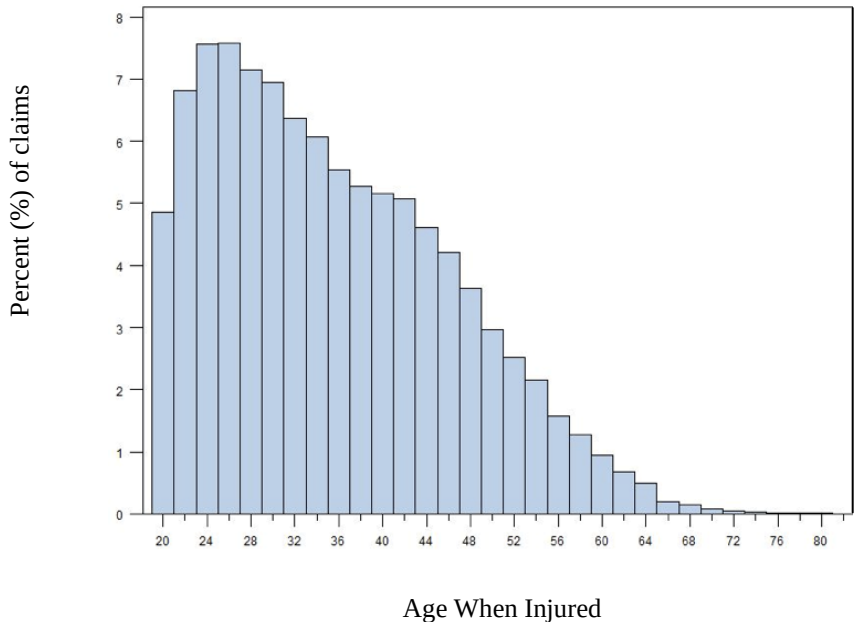


Figure 1. Age distribution at time of injury
Note. Average age: 35, SD: 11, Median Age: 33, IQR: 26-43, Range: 19-99,
Total number for claims: 107,064

Statistical analysis approach

The outcomes (cost, injury/illness cause and nature) and dependent (age) variables were evaluated in terms of their distribution and completeness. The dependent versus the outcome variables were plotted to identify outliers and trends in the data. Categorical and ordinal variables were derived where appropriate. The categories of the cause and nature of injury variables were collapsed in order to group the least frequently occurring categories. Thus, illnesses were not specifically studied within this project as all of them were collapsed into "other" categories. Cost variables were log-transformed for all statistical analyses because the criteria for normality was not met. Cost variables were also adjusted for inflation to the year 2010 by using the Consumer Price Index.

The frequency and mean cost (total, medical and indemnity) of the injury's or illness's cause and nature by age group was determined. Pearson correlations and point-biserial correlations were ran to determine the strength of the relationship between dependent variable and outcome variables. Analyses of variance were used to evaluate differences in mean cost (total, medical and indemnity) of a claim across age groups. Multiple pairwise comparisons using a bonferroni adjusted alpha level of .003 per test (.05/15) was used to compare differences between age groups and the mean cost of a claim (total, medial and indemnity).

Linear regression analyses were conducted in order to explain the effect of age (years) on cost (total, medical and indemnity) and the interaction effects of age and injury/illness cause and nature on cost. The following procedures were used:

<u>The effect of age (years) on cost</u>

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

The interaction effects of age on the association of injury cause and nature on cost

The outcome variables were also assessed by separate linear regression models for the explanatory variables cause and nature of injury/illness and their interactions with age (years) (see Figure 2). For example, the linear regression model for total cost and cause was:

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

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:

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

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 nature of injury for each year increase of age. For example, if the beta estimate for falls*age in the above model was .0124, and it 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.

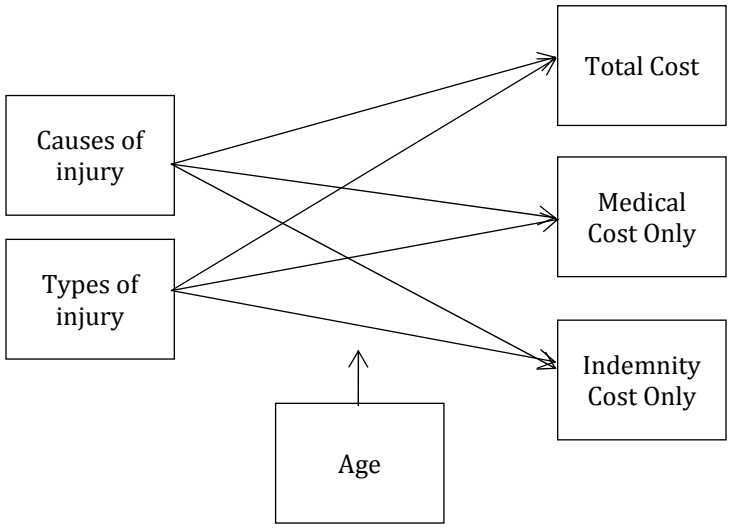


Figure 2. Diagram of relationships analyzed

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.

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, 34% 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 3). Older workers incurred more workers' compensation costs than younger workers (see Table 2).

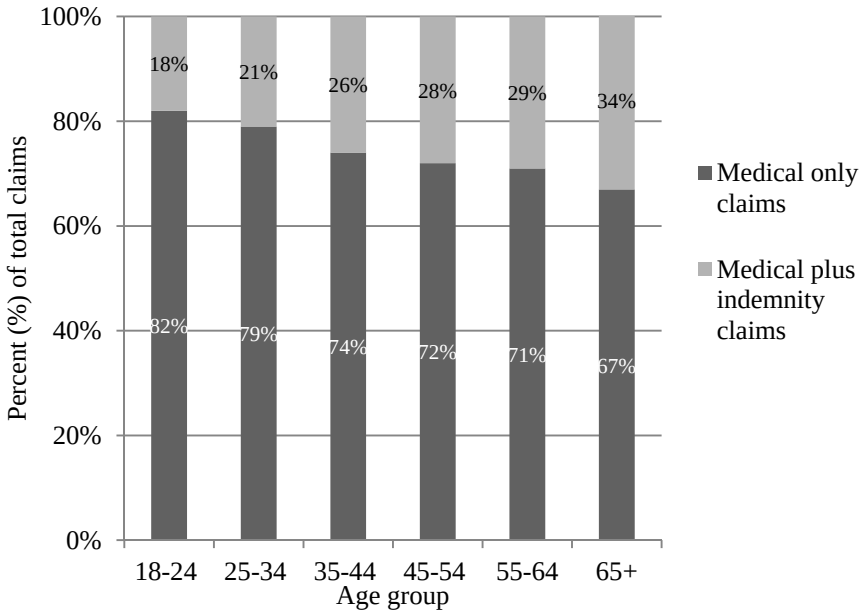


Figure 3. Claim type by age group

Table 2. Distribution of workers' compensation costs by age group

			Age group					
		Total	18-24	25-34	35-44	45-54	55-64	65+
		N=107,065	*n*=21,733	*n*=36,018	*n*=27,092	*n*=16,360	*n*=5,259	*n*=603
Total cost ($)	Mean	8,432	4,899	7,439	10,320	12,176	13,194	14,253
	(std) [+]	(37,637)	(31,935)	(34,063)	(39,287)	(48,943)	(44,404)	(37,170)
	Median	563	474	544	642	706	775	861
	IQR[^]	280-2,022	254-1,143	285-1,671	296-3,059	305-4,707	308-5,464	295-7,056
Medical ($)	Mean	3,709	2,424	3,284	4,207	5,551	5,632	5,275
	(std) [+]	(20,672)	(14,026)	(16,665)	(17,387)	(35,944)	(25,971)	(14,291)
	Median	521	450	507	582	631	674	718
	IQR[^]	261-1,450	240-963	267-1,275	274-1,897	278-2,630	279-2,837	268-3,054
Indemnity ($)	Mean	4,306	2,168	3,661	5,402	5,819	6,762	8,142
	(std) [+]	(21,676)	(20,295)	(20,710)	(24,075)	(19,851)	(24,386)	(25,809)
	Median	0	0	0	0	0	0	0
	IQR[^]	0-0	0-0	0-0	0-157	0-690	0-1,004	0-2,380

[+] Standard deviation
[^] Inter-quartile range
Note. Costs ($) adjusted for inflation to 2010 dollars. N=number of claims.

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 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).

Table 3. ANOVA multiple comparisons p-values for differences in mean costs by age group

	Age group					
	18-24	25-34	35-44	45-54	55-64	65+
18-24						
Total		<.0001	<.0001	<.0001	<.0001	<.0001
Medical		<.0001	<.0001	<.0001	<.0001	.0038
Indemnity		<.0001	<.0001	<.0001	<.0001	<.0001
25-34						
Total			<.0001	<.0001	<.0001	<.0001
Medical			<.0001	<.0001	<.0001	***.6643***
Indemnity			<.0001	<.0001	<.0001	<.0001
35-44						
Total				***.0218***	***.0159***	***.3318***
Medical				***.4869***	***.4262***	***1.000***
Indemnity				<.0001	<.0001	<.0001
45-54						
Total					***1.000***	***1.000***
Medical					***1.000***	***1.000***
Indemnity					***1.000***	***.0140***
55-64						
Total						***1.000***
Medical						***1.000***
Indemnity						***.1038***
65+						
Total						
Medical						
Indemnity						

Note. A bonferroni adjustment method was used (.05/15=.003).

Simple linear regression analyses were conducted to determine the relationship between cost of a claim and age of claimant. 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 (Specific Aim #2)

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 accounted for 29% of claims filed by workers over the age of 65. 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.

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. Cuts, punctures and scrapes occurred more frequently among younger age groups. 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 *n*=21,733	Rank	25-34 *n*=36,018	Rank	35-44 *n*=27,092	Rank	45-54 *n*=16,360	Rank	55-64 *n*=5,259	Rank	65+ *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

The relationship between causes of injury and cost by age group (Specific Aim #2)

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 4). 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 7). 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.

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 8).

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 5). 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 6). 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. 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.

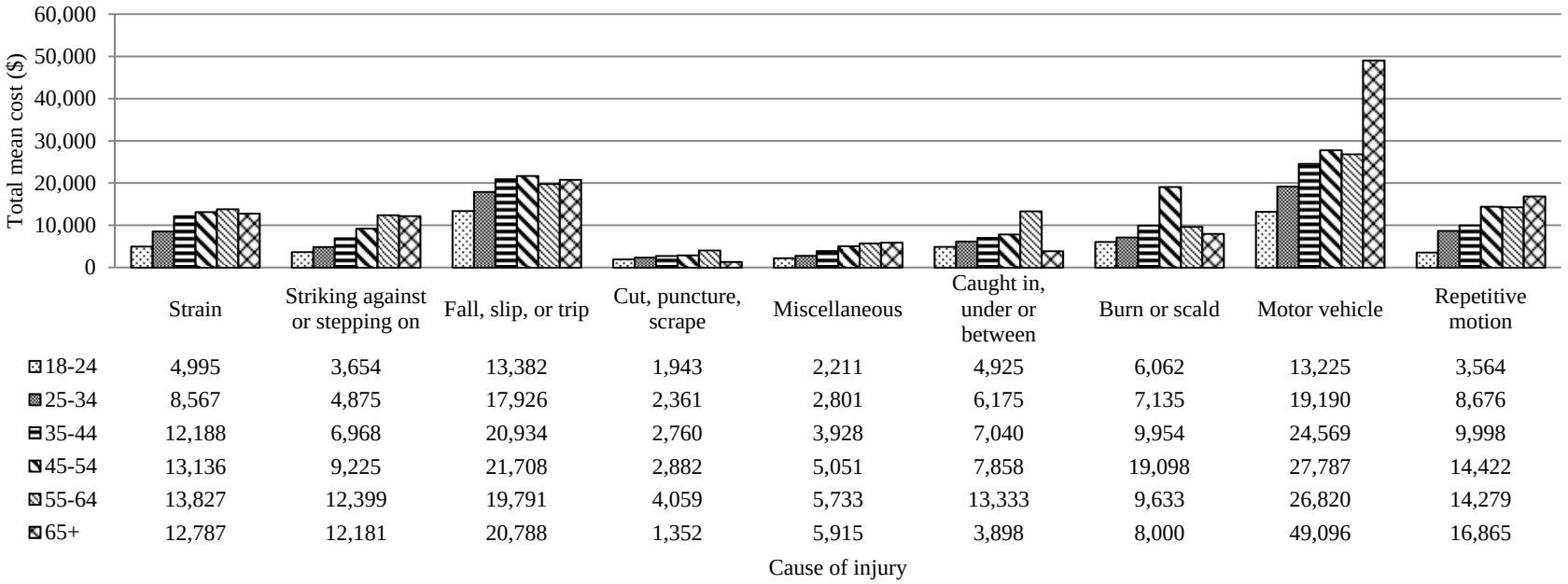


Figure 4. Total mean costs ($) of cause of injury by age group

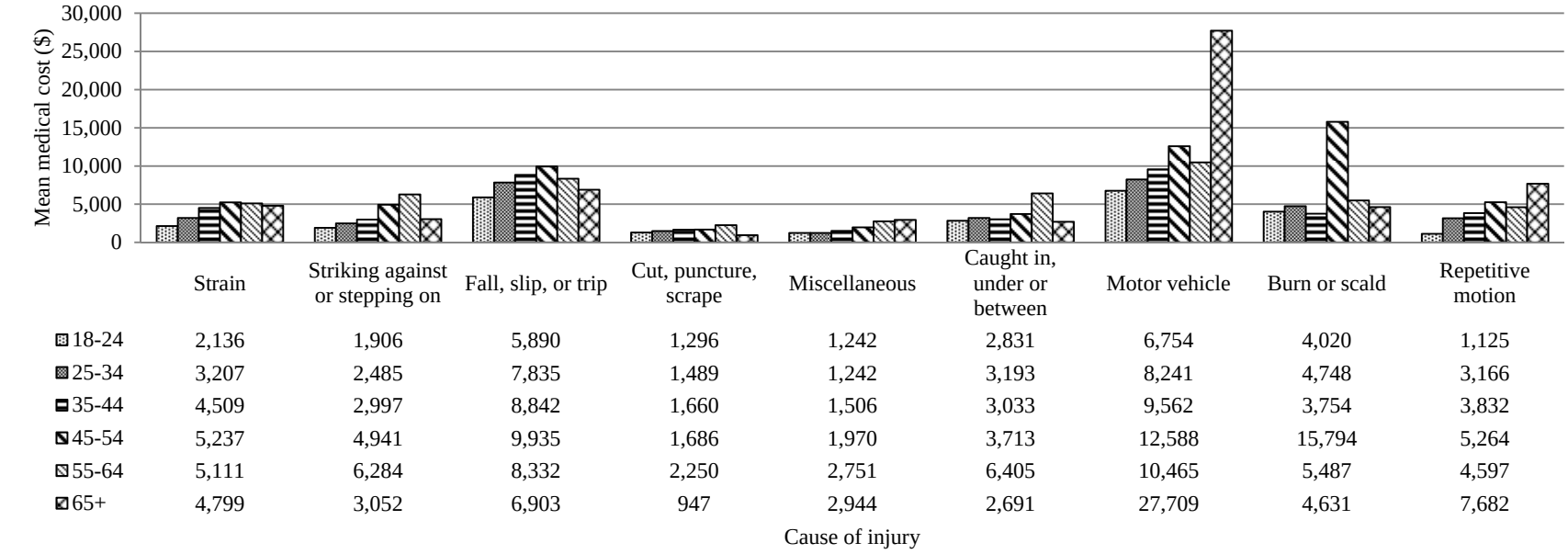
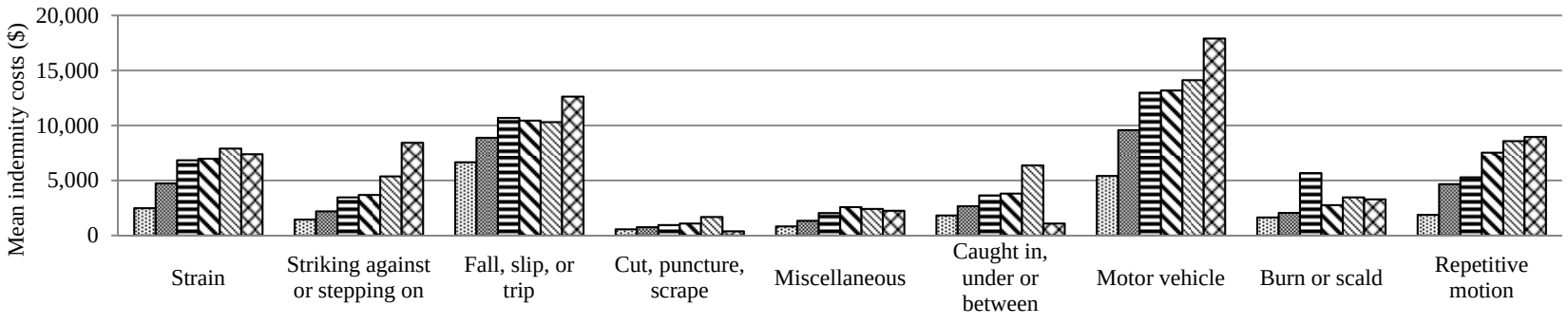


Figure 5. Mean medical costs ($) of cause of injury by age group



	Strain	Striking against or stepping on	Fall, slip, or trip	Cut, puncture, scrape	Miscellaneous	Caught in, under or between	Motor vehicle	Burn or scald	Repetitive motion
18-24	2,487	1,454	6,667	564	820	1,821	5,413	1,636	1,874
25-34	4,737	2,189	8,889	764	1,345	2,663	9,584	2,064	4,665
35-44	6,839	3,463	10,703	955	2,042	3,645	13,001	5,679	5,290
45-54	6,981	3,694	10,444	1,095	2,586	3,814	13,185	2,765	7,536
55-64	7,907	5,374	10,312	1,679	2,416	6,374	14,133	3,467	8,577
65+	7,390	8,438	12,640	383	2,250	1,096	17,912	3,290	8,974

Cause of injury

Figure 6. Mean indemnity costs ($) of cause of injury by age group

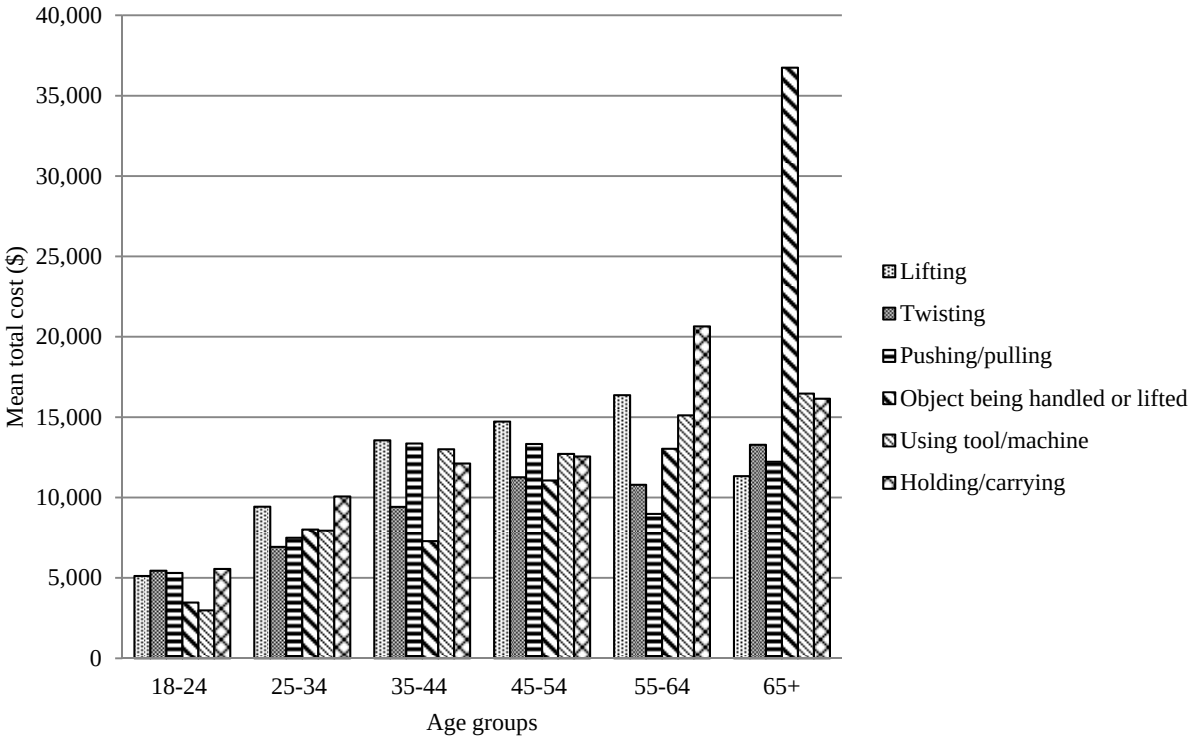


Figure 7. Mean total cost ($) of the most frequent strain causes of injuries by age group

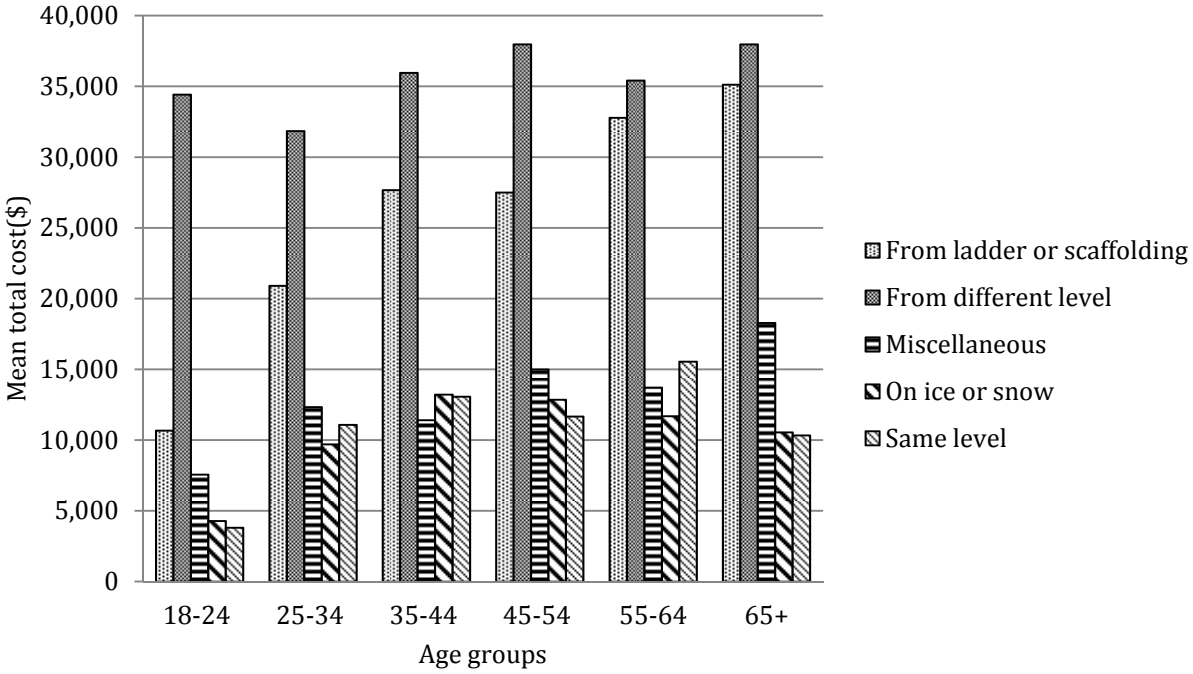


Figure 8. Mean total cost ($) of the most frequent fall, slip or trip causes of injuries by age group

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

[+]Cost variables log-transformed
[a]Parameter estimates for each category of cause of injury modeled together. SE= standard error.
[b]Slope estimate for type of cause of injury and cost by age when injured (years)
- Not significant in the final model

Description of nature of injury by age groups (Specific Aim #3)

The relationship between the nature of injury and age is described in Table 6. Over half of the injury natures 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 natures, 26% and 27% respectively. Lacerations, foreign body and punctures were most frequent among younger age groups. Small point-biserial correlations between nature of injury and age when injured were found to be significant. For example, positive point-biseral 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 nature of injury by age group

	Age group											
	Rank	18-24 *n*=21,733	Rank	25-34 *n*=36,018	Rank	35-44 *n*=27,092	Rank	45-54 *n*=16,360	Rank	55-64 *n*=5,259	Rank	65+ *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 nature of injury. "Other" was created for this study and includes all nature of injury possibilities that occurred less frequently (<1%).

The relationship between nature of injury and cost by age group (Specific Aim #3)

The most frequently occurring injury natures were not the most costly. Fractures comprised between 4 and 6% of all natures of injuries, but were the most costly natures of injury across all age groups (see Figure 9). Natures of injuries classified as "all other" were also among the most costly across all age groups. Since natures of injuries classified as "all other" were originally coded as such, this nature of injury could not be broken down by type further. Natures 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 natures that occurred the least frequently (<1%). The specific natures 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 natures 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 10). 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 11). 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 nature of injury and age on the association with cost of claims (see Table 7). In "step 1" linear regression analyses revealed that the relationship between nature of injury and cost of a claim was modified by age at the time of injury. The Type II SS for the nature 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 natures of injuries by age have equal slopes for all types of costs.

In the total cost model, the interactions with age were strongest for a sprain, 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 natures 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 natures 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 natures of injuries increased the indemnity costs of a claim by 3.4% for each year increase in age.

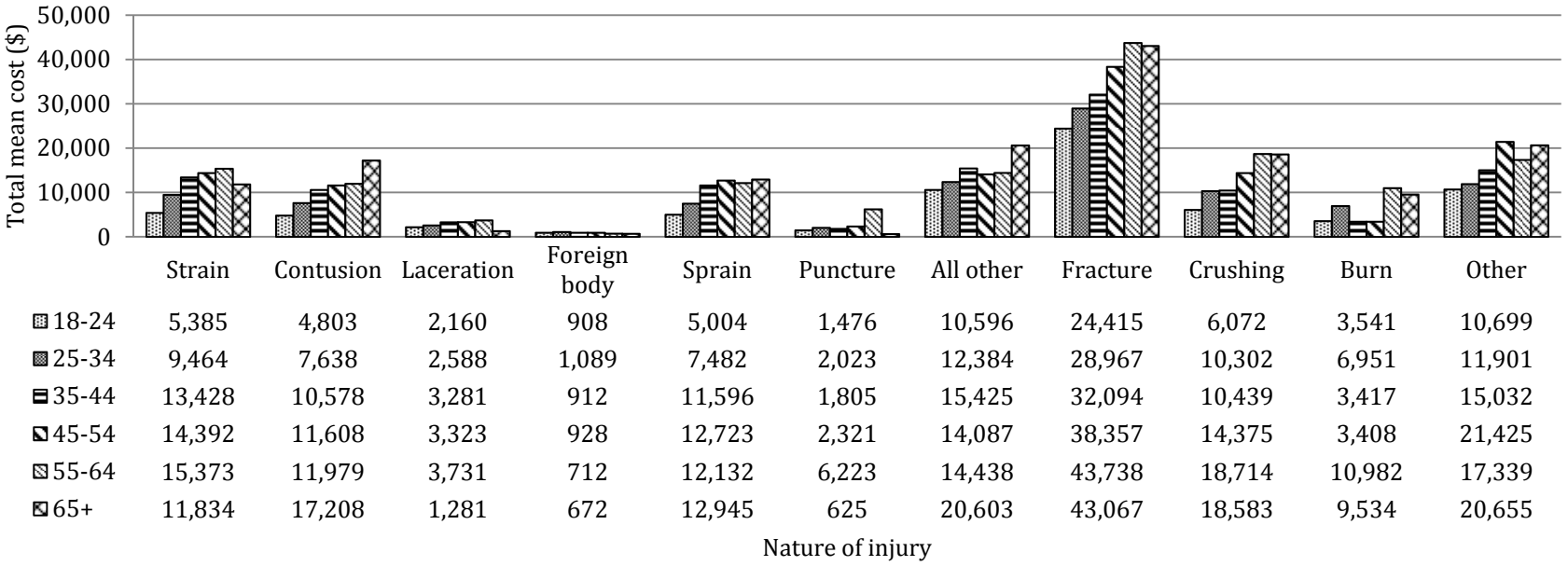


Figure 9. Total mean costs ($) of nature of injury by age group

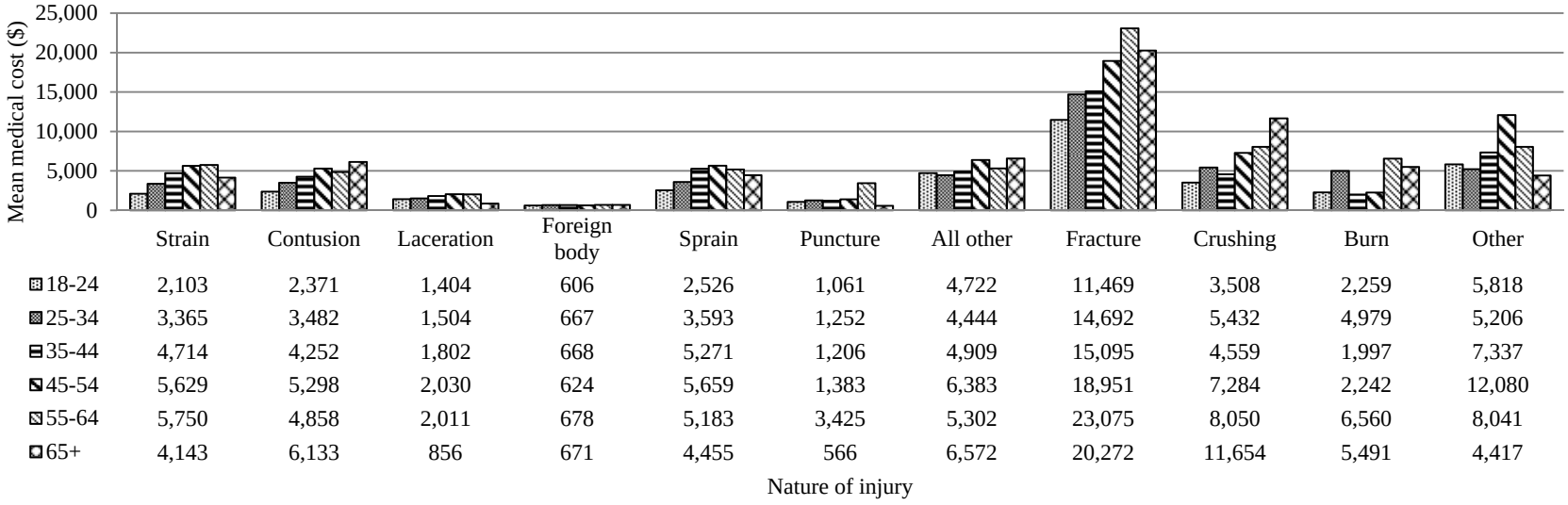
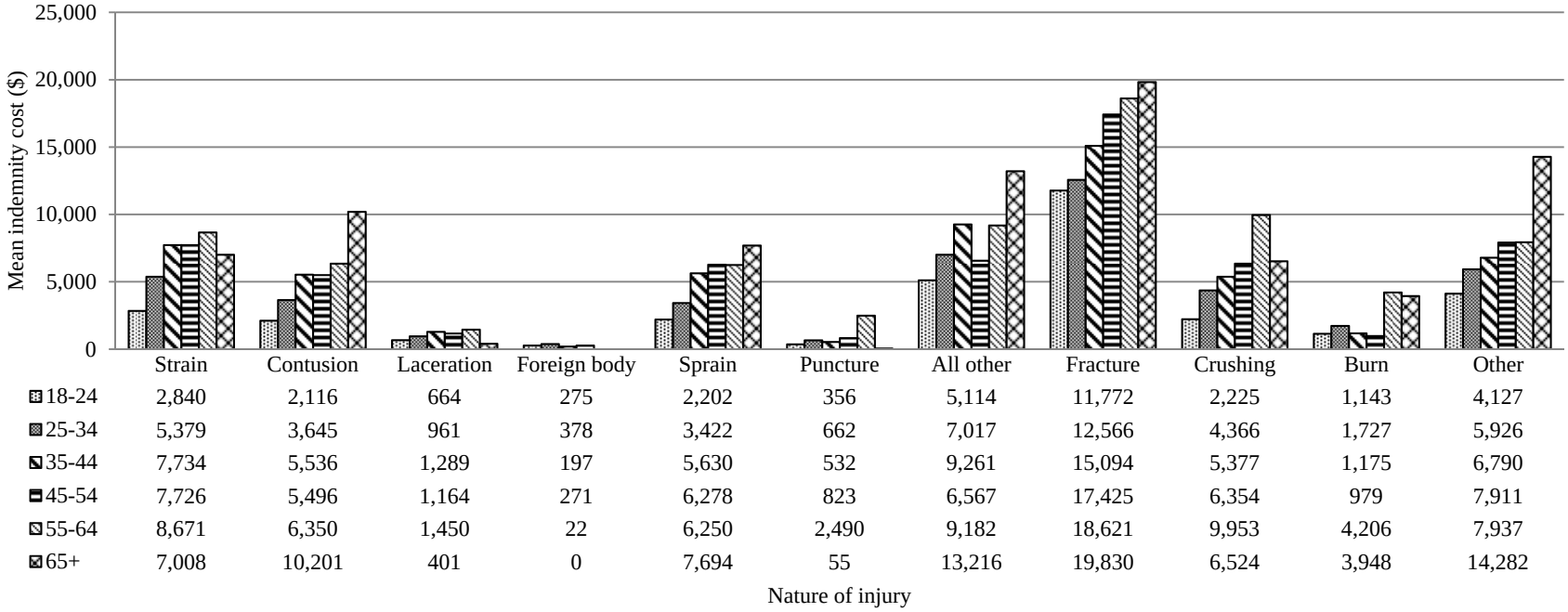


Figure 10. Mean medical costs ($) of nature of injury by age group



	Strain	Contusion	Laceration	Foreign body	Sprain	Puncture	All other	Fracture	Crushing	Burn	Other
18-24	2,840	2,116	664	275	2,202	356	5,114	11,772	2,225	1,143	4,127
25-34	5,379	3,645	961	378	3,422	662	7,017	12,566	4,366	1,727	5,926
35-44	7,734	5,536	1,289	197	5,630	532	9,261	15,094	5,377	1,175	6,790
45-54	7,726	5,496	1,164	271	6,278	823	6,567	17,425	6,354	979	7,911
55-64	8,671	6,350	1,450	22	6,250	2,490	9,182	18,621	9,953	4,206	7,937
65+	7,008	10,201	401	0	7,694	55	13,216	19,830	6,524	3,948	14,282

Figure 11. Mean indemnity costs ($) of nature of injury by age group

Table 7. Results from linear regression models for cost of a claim in relation to nature of injury and age of claimant

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

[+]Cost variables log-transformed
[a]Parameter estimates for each category of nature of injury modeled together. SE= standard error.
[b]Slope estimate for nature of injury and cost by age when injured (years)
- Not significant in the final model

Conclusions, Recommendations and Future Directions

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. Aging workers filed a small percentage of the total workers' compensation claims. Yet, it remains unclear whether or not aging construction workers have a higher rate of claim filing than younger construction workers as information regarding the number of workers the dataset represented was not available. Our results indicated that aging workers generally incurred more workers' compensation costs when they filed a claim. This was especially true for costs related to lost workdays, disabilities, physical limitations, etc. (i.e. indemnity costs). 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 aging construction workers and younger construction workers do in fact experience significant differences in injuries and costs.

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).

We will be continuing this research by investigating the three specific aims of this study in relation to the construction trade (as referenced by the NCCI coding scheme) associated with the workers' compensation claims. Our results will provide the construction industry with specific knowledge of the occupational injury and illness trends among different construction trades in relation to the age of a worker. Additional funding for this next step has been obtained from the NIOSH Mountain and Plains Education and Research Center pilot research grant program.

Publications and Presentations

Schwatka N. V., Butler, L. M., & Rosecrance J. C. [2012]. *Occupational injury epidemiology: An aging workforce and its effect on injury in the construction industry*. Epidemiologic Reviews 34(1): 156-167.

Schwatka N. V., Butler, L. M., & Rosecrance J. C. [under review]. *Age in relation to worker compensation costs in the construction industry*. Submitted to the American Journal of Industrial Medicine.

Schwatka, N. V., Butler, L. M., & Rosecrance, J. C. [November, 2011]. *Role of aging on the cost of construction injuries*. Roundtable session at the 139th American Public Health Association Annual Meeting. Washington, D.C.

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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		

Table 1. *(Continued)*

Code	
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. Nature 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		

Table 2. ***(****Continued)*

Code	Nature
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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